INTERNATIONAL GRAIN ORIGIN SWITCHING: CONTRACT WASHOUTS AND EMBEDDED SWITCHING OPTIONS

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ABSTRACT

Changing dynamics in the international grain trading industry have led to a rise in two new contracting practices colloquially termed washouts and switching options and formally defined as contract washouts and embedded origin switching options. When spatial arbitrage opportunities exist, grain buying firms switch from one origin to another. This thesis documents the increased frequency with which these contract practices have been used and examines the factors that incentivize firms to use them. Using data from 2018 to 2023, two models are developed with a binomial lattice that value these contracting terms. The results indicate that these practices have significant value, which is largely driven by price volatility and the correlation between prices at different international origins. This explains the observed increase in contract washouts and origin switching options in recent years, as grain prices have been characterized by higher price volatility.

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LIST OF ABBREVIATIONS

USG..Grain price at the United States Gulf of Mexico near New Orleans

PNW...Grain price at the United States Pacific Northwest near Portland

BRZ..Grain price at Paranagua, Brazil

ARG ....Grain price in Argentina port

UKR ....Grain price in Ukraine port

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1. INTRODUCTION

1.1. Overview

The grain trading industry is continuously evolving. Big changes on a global scale continue to drive innovation to the way that commodity trading firms conduct business. International grain prices are more volatile, which creates opportunities for firms poised to take advantage. Trading companies capitalize by altering the way they manage their grain contracts. There has been an increase in the number of contract washouts, a colloquial term for contract cancellation followed by a switch to grain procured from an alternative geographical origin. In some cases, this origin switching is negotiated as an option into the original contract, providing flexibility for the buyer. These are called embedded origin switching options for the purposes of this thesis. These new contract provisions are the topic of interest to this study.

1.2. Problem Statement

As grain prices continue to experience elevated volatility, incentives exist for grain firms to change origins to take advantage of price opportunities. Contract strategies are evolving, and firms need to find ways to value these new contracting provisions. This thesis proposes the use of real option methodology. This construct provides a way to value embedded flexibility and managerial optionality in assets, such as contracts. Quantifying the value of contract washouts and embedded origin switching options should allow firms to better manage their contracting strategies.

1.3. Objectives

The overall purpose of this thesis is to investigate novel contracting practices involving switching origins. Several specific objectives exist for this study. The first objective is to define these contract terms and document the increased occurrence of contract washouts and embedded origin switching type options. Trade information is not always disclosed, so this compiled list of occurrences is not exhaustive. Nonetheless, it is evident from the instances documented that these contract practices are occurring more often, which motivates the second objective. This study aims to provide a way to quantify the value of these contract provisions. Real options methodology is used to provide a conceptual framework. This is empirically accomplished with Monte Carlo simulation and a recombining binomial lattice to derive the option value. Sensitivity analysis on these models helps accomplish another objective: to demonstrate the important factors that make these provisions valuable to trading firms. This is an important goal of this study that has implications for the grain industry.

1.4. Procedures

To accomplish the objectives of this study, several procedures are followed. Background research informed the conceptual framework guiding the real option valuation which derives the value of the contract washout and embedded origin switching option. A recombining binomial lattice is used to value the option, with Monte Carlo simulation used to provide randomness to the prices at different relevant geographical origins. The resulting model is also modified to conduct sensitivity analysis on the relevant variables.

The first steps in this study involve documentation of contract washouts and embedded origin switching options which have occurred in the industry trade. From this understanding of industry practices, a conceptual framework is built to guide the real option valuation. This methodology borrows the constructs of financial options to value flexibility embedded within assets. There are multiple empirical ways to calculate real option values, but the best fitting method for contractual assets is the binomial lattice. It is built using price data and assumptions from a hypothetical base case which represents the most likely real-world case. Due to the construct of the recombining lattice, the price data is transformed to spreads from the price at the U.S. Gulf. The model output is the mean value of these contract provisions. Sensitivity analysis further isolates important factors and illustrates how changes in these variables drive changes in the mean value of the contract washouts and embedded switching options.

1.5. Organization

This thesis contains six chapters. Chapter 1 serves as an introduction to the study, highlighting the pertinent problem and outlining objectives and procedures followed. Chapter 2 provides an in-depth background on the global nature of the grain trading industry and its changing dynamics, spatial arbitrage opportunities and the contracting provisions which allow firms to realize them, and the increasing occurrence of contract washouts and embedded origin switching options. Chapter 3 investigates real option methodology. In this chapter, the underlying framework for the model in this thesis is presented. Chapter 4 deals with the application of the real option methodology to the topic of study: contract washouts and embedded origin switching options. Included in Chapter 4 is a discussion of the price data used to derive results from the models. These results are presented in Chapter 5, which includes discussion and analysis of the findings. These findings are summarized in Chapter 6, which provides conclusions from this study while also discussing the limitations of this research and the potential for future work.

2. BACKGROUND

2.1. Introduction

The commodity trading industry is always undergoing change. Macroeconomic forces, globalization, industry consolidation, technological innovations, and agricultural advancement alter the landscape for commodity trading firms. For firms to grow, they must be ready to adapt to new industry environments and meet the needs of market participants on a global scale. This allows firms to develop a competitive advantage. Firms may do this in multiple ways, including by having access to more markets and information, building more efficient infrastructure, or producing or processing at a lower cost per unit. One of the most common strategies used by commodity trading firms today is building economies of size and scale.

Economies of size and scale is defined by Kenton (2022) as "cost advantages reaped by companies when production becomes efficient." Size of the business helps drive these cost savings from efficient production. This leads to benefits for the companies. Caves (1977) was one of the first to document the market structure of the grain trade and shows how economies of scale help larger firms. There have traditionally been a few firms that dominate the international market, known as ABCD (ADM, Bunge, Cargill, and Dreyfus). These firms had advantages from their scale in terms of their physical facilities and their possession of intangible, asymmetric information (Caves 1977). Of course, the industry has evolved since then, but economies of scale are still advantageous.

Commodity trading firms may try to realize economizes of size and scale by growing their company from within, which involves buying assets, building facilities, and creating teams of employees to expand their geographical footprint into new markets or develop new efficiencies. An example of this recently is the planned creation of three new soybean processing facilities in North Dakota. Commodity trading firms recognize the potential for profit from processing soybeans in North Dakota, so companies like ADM, CGB Enterprises, and Epitome Energy are building facilities to take advantage of this new market. These new facilities are going to crush soybeans into oil used to make biodiesel. The by-product, soybean meal, can be used for livestock feed. In this region of the upper Midwest, there may not be enough demand for this meal, so companies like AGP are looking to expand their exporting facilities capable of handling soymeal (Plume 2022). This is part of building economies of size and scale in order to gain a competitive advantage.

While there are examples of companies expanding from within, there are many firms who have instead increased the size and scale of their business through mergers and acquisitions. These firms recognize the importance of finding efficiencies and achieve that goal by combining with or buying other companies. A recent example of this is Bunge's proposed merger with Viterra. If approved, this major merger of agricultural trading giants would create one of the largest trading companies in the world. The merger would allow for expanded networks of assets across the world, including in important markets of the United States, Brazil and Argentina, and Australia. This proposed deal comes not long after Viterra acquired Gavilon in a purchase in 2022. The CEO of Bunge said that the assets and the teams fit together, making this a strategic merger (Plume et al. 2023). This example highlights how trading firms seek to achieve competitive advantages through mergers and acquisitions due to increased economies of size and scale. As evidenced, the nature of these pursuits is on a global scale.

2.1.1. Globalization

The importance of globalization was recently highlighted in an article discussing the success of the Louis Dreyfus company in 2023. Company executives refer to their global footprint in the grains division as a key to their success, with specific mention of good Brazilian production and strong Chinese demand creating opportunity for the global merchant and processor. They also credit new investment in Argentine and Brazilian facilities as a driver of success in a time of persistent trade flow challenges in international grain trade (Reidy 2023).

Globalization has had an important impact on the agriculture industry and agricultural commodity trading specifically. Domestic agriculture prices are driven by global supply and demand market forces. The emergence of South American countries as major agricultural commodity exporters has dramatically impacted agricultural commodity flows around the world. Analyzing the market share of Chinese soybean imports from the United States and Brazil, Scheresky (2021) shows how over the past decade South American soybeans are favored for most of the year, with the United States being the preferred soybean origin from December to March and South America capturing Chinese demand the rest of the year. In this study, Brazil accounted for nearly two thirds of China's soybean imports. Additionally, the increased production in this region has influenced both exchange-traded futures prices and basis levels internationally.

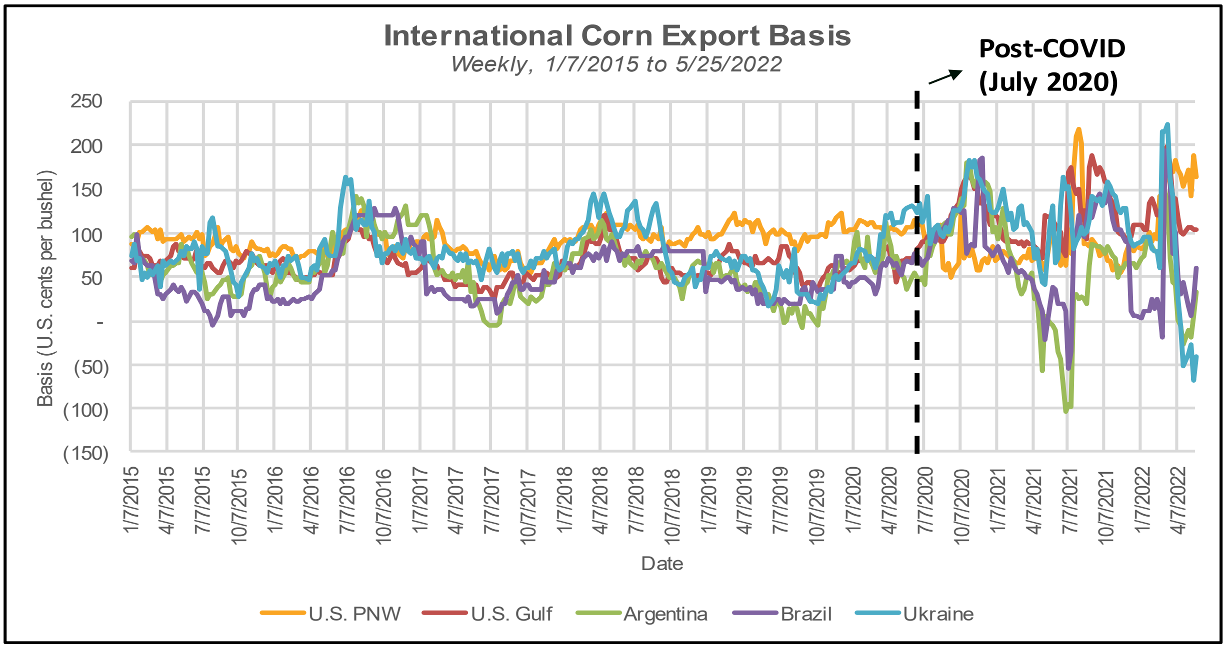
2.1.2. Global Grain Prices

Many factors influence futures and basis prices for commodities. In recent years, there has been increased volatility of both futures and basis levels. A recent study of commodity volatility determined major drivers of variance include changes to expected interest rates, inflation uncertainty, changing market structure, commodity index trading, and news about the future state of the economy and commodity supply and demand (Watugala 2019). Factors like these have driven us into a new era of crop prices. Irwin and Good show that this new era began in December of 2006 and has persisted until the present time (Good and Irwin 2023). In 2008, they projected average monthly prices for corn, soybeans, and wheat that have been correct with less than two percent error. Around this average, there is a trading range. However, agricultural commodity prices are generally thought to be mean reverting. This is due to the fact that when the price rises, more of the commodity is produced. This increase in supply without increased demand drives prices back towards the mean. Conversely, when price falls, production shifts towards other commodities. Lower production with the same level of demand moves prices back towards the mean. Even though agricultural commodity prices exhibit mean reverting tendencies, there can be significant variation around the mean. In this new era of crop prices documented by Irwin and Good, there has still been much variation around the nominally higher mean.

Commodity futures prices reflect overall supply and demand, but basis and transfer costs are the primary determinates of spatial price relationships that commodity trading firms manage (Skadberg et al. 2015). Basis values are determined by local supply and demand, transportation costs, and other factors. The global basis has been experiencing increased volatility.

Bullock et. al show that a significant structural change in the basis for corn occurred in July of 2020, a few months after the onset of the COVID-19 pandemic. In their study, they track the 5 major global basis locations and show post-COVID basis volatility is significantly elevated (Bullock, Bullock and Wilson 2023). This can be seen in Figure 2.1. There was significant structural change evidenced by significant price differentials internationally, with prices varying greatly due to geography, quality, and logistical risk (Wilson 2023). Volatility in basis values is related to volatility of transportation costs.

Figure 2.1. International Basis Levels



Source: (Bullock et al. 2023).

For international trade, ocean freight is the primary transfer cost, and it is also experiencing increased volatility. Factors driving this volatility include trade flow disruptions, such as those from war and pandemics (Sadden 2022b; Sadden 2022a). Of course, volatility in commodity markets themselves drives volatility in the demand for the vessels to move grain internationally. This logistical piece of commodity trading is another increased risk that firms must manage to stay profitable.

It is the increased volatility in basis and freight which creates differentials among origins that leads to the topic of study for this thesis: washouts and origin switching options. As basis and freight prices change, the lowest cost origin for the grain buyer changes. These price differentials create opportunity for spatial arbitrage, which is a type of physical arbitrage described by Pirrong (2014) as involving moving commodities from production regions to where they are consumed. In doing so, commodity trading firms take advantage of price differentials to find profit.

2.1.3. Spatial Arbitrage

Spatial arbitrage opportunities exist due to price differentials between different geographical areas. These differences are likely to be larger for greater distances. Many factors lead to spatial arbitrage opportunities. On the international level, black and grey swan events are often drivers of these opportunities. “A black swan is an unpredictable event that is beyond what is normally expected of a situation and has potentially severe consequences” (Chappelow 2020). Black swan events completely disrupt the normal flow of goods, including commodities, and thus they create large price differentials. These prices changes occur due to demand or supply shocks in different areas of the world. Notable black swan events in recent history include the Covid-19 Pandemic and the 2008 Financial Crisis. Both events caused major disruptions to trade around the world, which in turn caused demand and supply shifts of different commodities, leading to price differentials that turned into opportunities for spatial arbitrage for firms posed to take advantage.

Grey swan events are similar to black swan events in that they cause major disruptions; however, they are predictable, even though they are very unlikely (Liberto 2022). Meersman, Rechsteiner, and Sharp (2012) use an example of a tsunami in Japan in 2011 to illustrate the effects of a grey swan event. After a tsunami hit the island country, nuclear power plants had to shut down. This led to an increase in demand for natural gas as an energy source, driving up the price of natural gas. Commodity trading firms that were located in Japan were able to take advantage of the elevated prices as a profit opportunity. Local firms were limited to the supply they could get, but large international firms could source the natural gas elsewhere and distribute it through their locations in Japan. This illustrates how geographically diverse firms were posed to participate in the spatial arbitrage opportunity from a grey swan event. This is just one way that firms maneuver to find profits from spatial arbitrage.

Market participants want the optionality to engage in spatial arbitrage opportunities that are occurring more often due to increased volatility in basis and freight. Dynamic changes have led to new industry practices regarding the option for buyers to switch origins or to washout contracts, which are terms that are defined in the next section. These practices allow grain buyers to switch from the origin they originally contracted to buy grain to a lower cost origin before physical delivery is made and physical settlement of the contract occurs. The rise in popularity of these contracting practices comes in part from consolidation and increased market power for grain buyers that allows them to demand more optionality in their contracts.

2.2. Grain Trade and Contracting

2.2.1. Grain Contracting Provisions

Cash contracts for grain commodities are privately negotiated between parties. Unlike futures contracts, which are settled through a clearinghouse, forward cash contracts can include non-standard provisions. However, they are also subject to counter-party default, which is defined as one party failing to make all the payments required by the contract (Zhu and Pykhtin 2008).

Contract defaults are colloquially termed washouts. Other related terms used include counter-party risk and cancellations. Kimura studied counter-party risk and distinguishes two types of defaults: strategic and non-strategic. He defines a strategic default as one where defaulting on the contract is more beneficial than honoring the original contract. On the other hand, a non-strategic default is one that occurs when factors out of the contracting parties control render one or both parties unable to fulfill their contractual obligations (Kimura 2016). A washout as discussed in this study is considered to be a strategic default by the purchasing party.

In industry practice, washouts are prevalent with large, international grain buyers. One example would be Chinese soybean buyers on the international market. According to Donley, Chinese importers account for 60% of the world's soybean demand (Donley 2023). Because they are the largest importers of soybeans and have considerable market power, sellers of grain are forced to continue to transact with them, even after defaults. As an alternative to washouts from ex post negotiations, embedded switching options as a contract term give the buyer the option to take advantage of the opportunity that would lead to a strategic default while compensating the seller by giving them option premium.

The option to switch origins has much more value for more homogonous commodities like corn and soybeans. For many grain buyers, they are sourcing from a certain location in order to secure a certain quality. For millers of wheat and other cereal grains, quality is one of the foremost considerations, and so price differentials between origins is less important than the quality available from different potential sources (McPike 2023). However, for large grain buyers who have uses for multiple quality designations or for buyers of commodities that are more homogenous, price differentials between origins are more enticing and thus they are more likely to demand optionality to switch or to strategically default on, or washout of, their contracts. This has implications for both domestic and international grain trade.

2.2.2. Domestic Grain Trade

The commodity trading industry is undergoing considerable consolidation. While international grain trade is becoming more competitive with the evolution of new markets, the domestic market is becoming more and more dominated by large firms who have vertically integrated all along the value chain of grains and oilseeds. These firms term themselves "supply chain managers" and have internalized many of their logistical needs. As these companies increase their geographic footprints and overall market power, they reduce their need for domestic trade.

Nonetheless, specialized markets and mid-sized trading firms still trade grain domestically. New contract provisions are a part of continued industry evolution as firms navigate shifting dynamics that demand flexibility and tactfulness. While these newer contract settlements and contract provisions affect international grain trade, there is potential for their rise in domestic contracts as well. However, there are provisions in the Commodity Exchange Act prohibiting trade options, so the use of these contract provisions in the U.S. domestic grain trade is restricted.

2.2.3. International Grain Contracting

In the global economy, grain contracts between traders from different countries are common. In fact, the North American Export Grain Association (NAEGA), a group whose mission is to support efficient international trade of grains and oilseeds, reports that 30 percent of all grain and oilseed produced is traded internationally (NAEGA n.d.). Many factors affect the efficiency of international trade.

Tenders, or auctions, are an important function in international grain trading. These may be public or private, with varying amounts of information released to other market participants. This type of auction is common to the agriculture trade as it helps buyers who may have uncertainty about production costs find the lowest cost seller. In the past, tenders were especially prominent for government buying and selling organizations. Despite recent increased privatization of many countries' importing functions, auctions have remained common; however, there is less formality and often less transparency to the market.

NAEGA is concerned with both tariff and non-tariff trade barriers that can prevent buyers and sellers from transacting. Well written, enforceable contracts are a tool to improve the efficiency of trade. In recognition of this, NAEGA offers a standardized FOB contract that American and Canadian grain exports can use to model their contracts. The standard contract from the NAEGA is called the FOB No 2 or NAEGA 2. Similarly, the Grain and Free Trade Association, which is based in London, develops standard contracts. According to their website, they estimate 80% of the world's grain trade utilizes their standard form of contracts (GAFTA n.d.). Their general grains contract is Contract No. 64 for Bulk Grain in FOB terms.

These standard contracts are available for grain buyers and sellers. While it is common for these contracts to include provisions outlining how default is handled, there is nothing related to contract washouts or optional origin contracts. This is due to the more unique nature of these contract settlements. Additionally, these contract settlements are often negotiated after the fact rather than as a contract clause. However, because of their increased occurrence as highlighted above, it is appropriate for further research into this matter.

2.3. Definitions and Examples

2.3.1. Definitions and Distinctions

A washout is a colloquial term that industry sources use to describe a cancellation. As such, there is ambiguity in how the term is used by trade participants. There appears to be multiple interpretations of the meaning of washouts. To some, washout implies a cancellation accompanied by a replacement with similar quantity from a different origin. To others, the term is used more strictly to describe a contract cancellation. For purposes of this thesis, a washout is described as a contract cancellation from one origin with a subsequent switch to an alternative origin. Cancellations may be equated to counter-party default on the part of the grain buyer. Some contracts include clauses which strictly define circumstances under which these cancellations are allowed. However, the washout or cancellation is often negotiated after the original contract agreement. It is important to note that many buyers do not have enough market power to propose changes to the contract terms, but large grain buying firms and import organizations are able to demand such negotiations.

Washouts are not to be confused with wash trades, which are a domestic phenomenon and prohibited by the Commodity Exchange Act. The Commodity Futures Trading Commission (CFTC) defines a wash trade as, "Entering into, or purporting to enter into, transactions to give the appearance that purchases and sales have been made, without incurring market risk or changing the trader's market position" (CFTC n.d.). Wash trades are related to futures transactions and regulated trading exchanges. Similar to this, the IRS prohibits the deduction of losses from wash sales, which are defined as selling a security for a loss and purchasing the same security 30 days before or after the sale (IRS).

Another term that is related is a washout hedging contract. This is a hedging instrument available from select brokers. They connect buyers who want optionality with a grain seller who can offer it to them. This type of contract allows a buyer to purchase the option to buy grain at a certain origin, but they are not locked into a contract there. Rather, they can execute or cancel the contract if another origin becomes more attractive due to price or quality reasons (McPike 2023). This would be similar to a contractual switching option.

An option to switch may be negotiated as an embedded term of the contract, or it may be negotiated afterwards as part of a washout (ex post contracting). Switching options are different than the cancellation of contracts, and this involves switching from one origin, which was originally agreed upon in the contract, to another, lower-cost origin. This type of optionality may become increasingly desired by commodity trading participants. As Meersman said, the most successful commodity trading firms in these times of industry evolution are those who “master optionality” (Meersman et al. 2012). For this reason, it is the topic of study for this thesis. The definitions presented above are summarized in Table 2.1.

Table 2.1. Definitions

Term	Definition	Related to
Cancellation	Occurs when one of the contractual parties reneges on their obligations	Default
Washout	A strategic default where defaulting on the original contract is more beneficial than honoring it, followed by a switch to a lower cost origin.	Cancellation, Default
Embedded Switching Option	An option written into a contract that allows for the buyer of option to change the origin of the grain later.	Optional-origin Contracts

2.3.2. Brief Review of Literature

There have been previous studies focused on switching options; however, these are largely unrelated to the switching options as they have been defined in this thesis. Many studies relate to options on futures contracts and other financial derivatives. An example of this is the switch option for arbitrageurs who are short cash and long treasury bond futures as defined by Barnhill and Seale (1988).

Several studies focused on switching options similar to those addressed in this study. Sødal, Koekebakker and Aadland (2008) used a real option model to value the flexibility of market switching between dry bulk markets and wet bulk markets for combination carriers. Bastian-Pinto, Brandão and Hahn (2007) modeled the option for a processor of sugarcane to choose between sugar and ethanol as an output. Johansen (2013) studied the value of geographical diversification for commodity trading firms, and showed that access to several markets and the ability to originate grain from different parts of the world had significant value. Hanson (2020) built upon this work by showing how an origin type switching option could provide value to sellers of grain by allowing them to fulfill contractual obligations from multiple origins. These studies were related to the issue addressed in this thesis, which is motivated by the increase in the occurrence of these practices. This increased frequency of contract washouts and embedded origin switching options is highlighted in the next section.

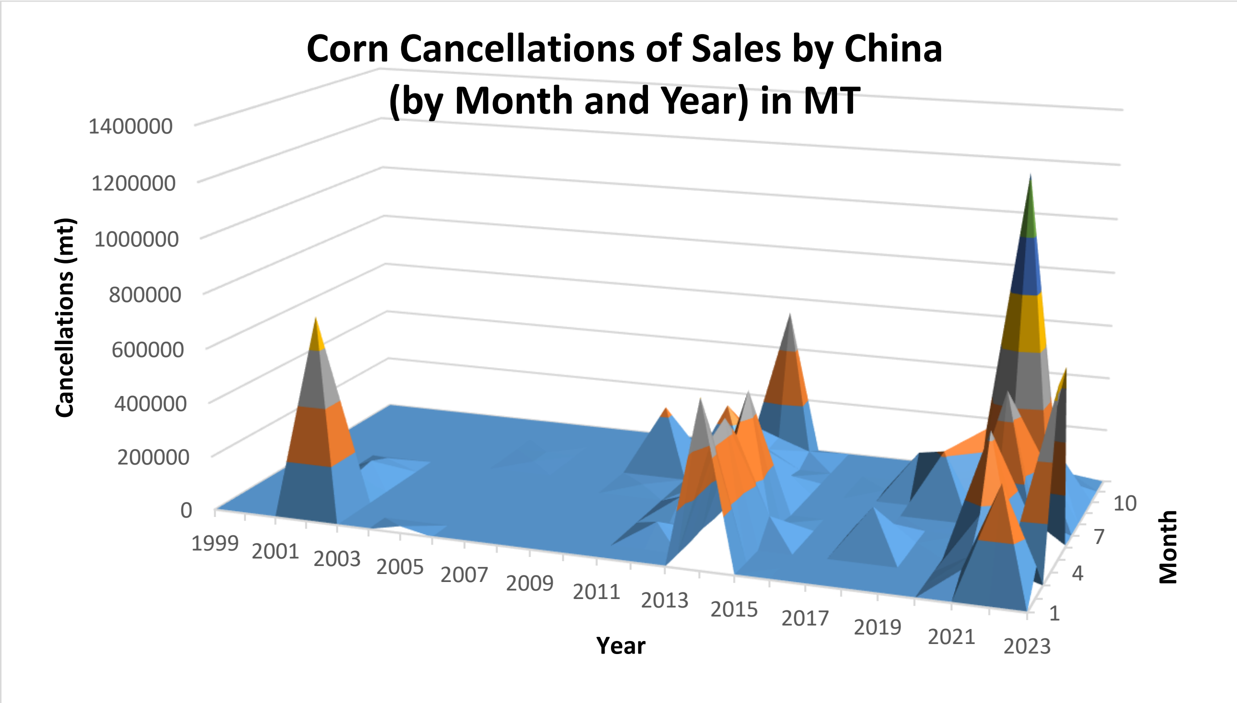
2.3.3. Industry Examples

The commodity trading industry changes discussed above have come with new industry practices. Buyers and sellers are transacting in new ways as they adapt to new industry environments. There are many examples of new contract strategies being implemented by both buyers and sellers of grain as it moves from producers to end-users. These are described in this section.

2.3.3.1. Frequency of Cancellations, Washouts, and Origin Switching

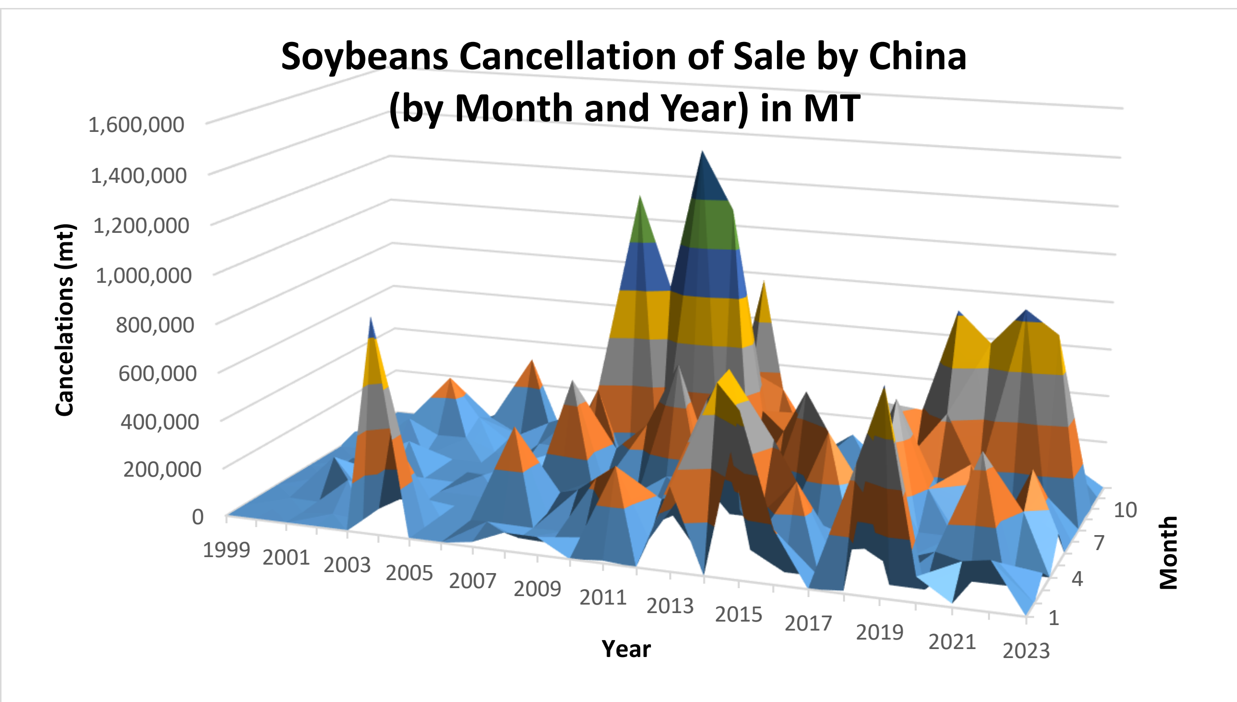
USDA export sales reporting system data shows that there has been an increase in cancellation of U.S. sales. Looking specifically at cancellations of grain originally destined for China, this occurrence appears to be escalating. Figures 2.2 and 2.3 show how China has cancelled grain contracts from 1999-2023. By cancelling their obligations, they have the optionality to find other sources of grain.

Figure 2.2. Corn Sales Cancellations by China



Source: Foreign Agricultural Service (2023)

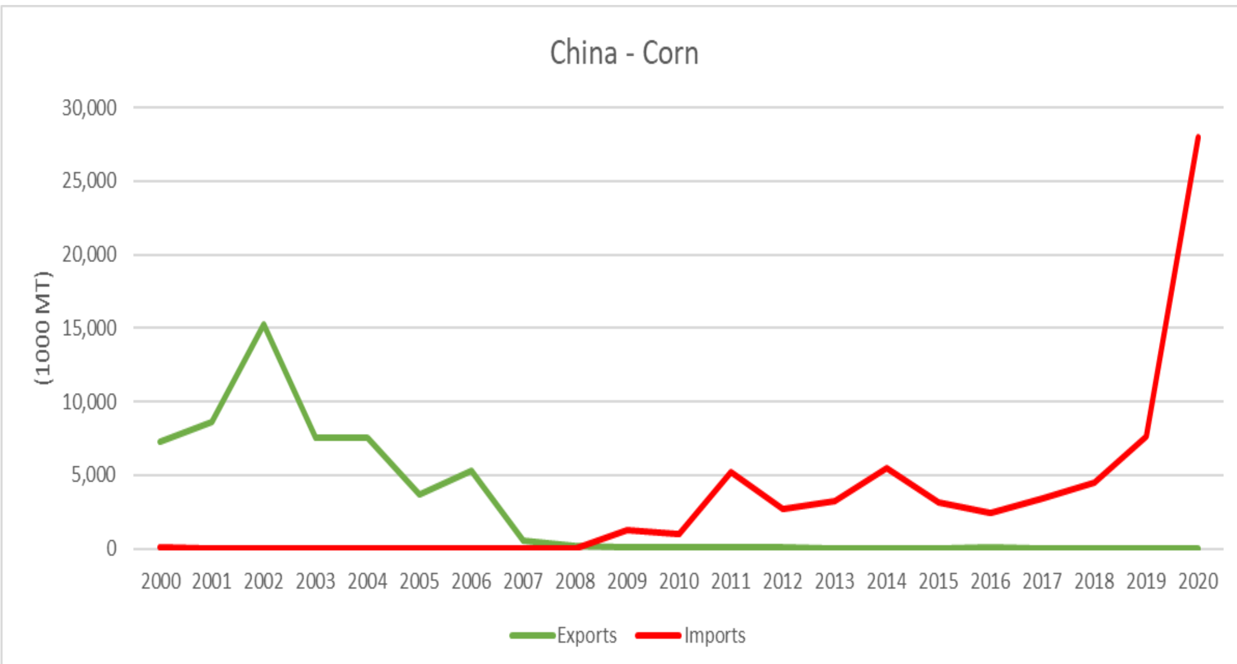
Figure 2.3. Soybean Sales Cancellations by China



Source: Foreign Agricultural Service (2023)

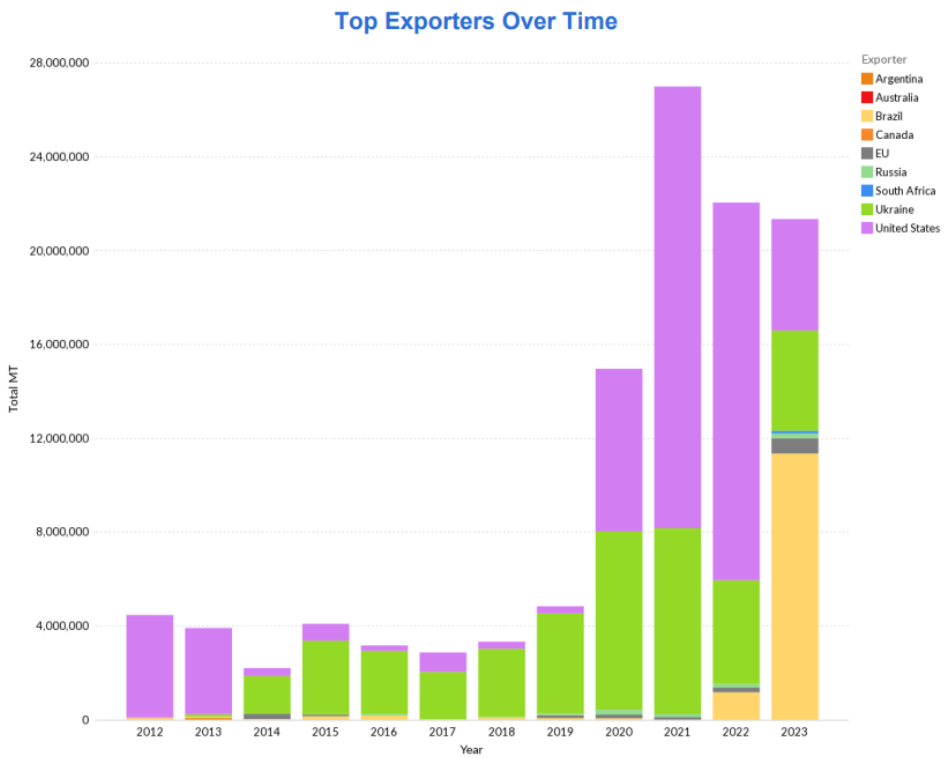
These figures suggest that China has cancelled purchases of U.S. corn and soybeans more frequently in recent years. This practice has been common for soybean contracts, and more recently corn. This increase in cancellation of corn contracts is happening concurrent with China's growth of corn imports, as seen in Figure 2.4, which shows Chinse imports and exports of corn over the past 20 years. China has become a major importer of corn, with a large increase in import demand occurring in 2019. At the same time, Figure 2.2 shows how Chinese buyers have cancelled previous sales made by U.S. exporters.

Figure 2.4. Chinese Corn Imports



China may be cancelling U.S. purchases to switch origins to other countries. Figure 2.5 shows the top exporters of corn to China over the past ten years. This figure makes it clear that competition for Chinese demand between exporting countries has increased. This may explain why China has cancelled contracts for U.S. corn: to switch to a more competitively priced origin in South America or the Black Sea.

Figure 2.5. Top Corn Exports to China



Source: AgriCensus

Chinese cancellations illustrated in the above figures demonstrate how contracts have been increasingly settled without physical delivery. It is not clear if China washed out of these contracts in order to switch to another origin; however, it is apparent that origin switching accounts for many of the reported cancellations of U.S. corn and soybean exports.

2.3.3.2. Documented Instances of Washouts and Switches

Recently, contact cancellations, colloquially termed washouts, have become more prevalent. There have been many news reports of washouts by China, Egypt, and other international grain buyers. Examples are listed in Table 2.2 and discussed below. This list is not exhaustive as not all occurrences are disseminated as public information. These examples were extracted from trade sources including Eikon, AgriCensus, RJObrien, Tierney, and personal communications. Nonetheless, these examples are representative and show many different reasons why these washouts might take place. Chiefly, price competitiveness incentivizes buyers to washout contracts. However, there are other considerations such as quality, logistics, and politics.

Table 2.2. Examples of Washouts and Origin Switching

Date	Commodity	Buyer	Seller	Details	Reference
Mar-24	Wheat	China	U.S.	China cancelled over half a million tons of US wheat shipments, due to their ability to purchase wheat cheaper at other origins.	(Hirtzer and Veloso 2024)
Feb-24	Soybean	China	U.S.	China switched from April 2024 U.S. Gulf to May 2024 Argentina	(Connor 2024)
Dec-23	Soybeans	China	U.S.	China paid unnamed U.S. exporter 15 cents/bu. for an embedded switching option.	(Jacques 2023)
Dec-23	Soybeans	China	U.S.	China bought soybeans using optional-origin language for U.S. and Argentia origins.	(Connor 2023b)
Dec-23	Corn	China	Brazil	China washout out of Brazilian purchases as Brazil prices skyrocket. Rumored to have switched to U.S. PNW.	(Connor 2023a)

Table 2.2. Examples of Washouts and Origin Switching (continued)

Date	Commodity	Buyer	Seller	Details	Reference
Nov-23	Wheat	China	France	At the request of China, December shipments were postponed to March and other booked sales cancelled as U.S. and Australian wheat became a cheaper origin.	(Balf 2023)
Oct-23	Soybeans	China	Brazil	8-10 cargoes rumored to have been washed out of Brazil. US Gulf is more price competitive and big firms can crush in Brazil for cheaper than in China.	(Li and Tinti 2023)
Oct-23	Soybeans		U.S. Gulf	Rumors of washouts due to logistical concerns causing higher freight prices	(Hughes 2023)
Sep-23	Soybeans		US PNW	Cancellations off the PNW switched to South American origins (10 cargoes)	(Nystrom 2023; Tinti 2023b)
Apr-23			Ukraine	Washouts from vessels at the entrance to the Black Sea, as they aren't ready to risk entering hostile waters	(Agricensus Staff 2023)
Feb-23	Soybeans	China	Argentina	China's Sinograin washed out of as much as 1 mmt and replaced with Brazil due to large price differential between the two South American countries	(Tinti 2023a)
Dec-22	Corn	Vietnam	Americas	Vietnam washed out of grain contracts with Vieterra and Olam in favor of closer origins	(Prykhodko 2022)
Oct-22	Soybeans	China	U.S. Gulf	Optional Origin Cargos switched from US Gulf to PNW due to transportation disruptions on the Mississippi River	(Tinti 2022b)
Sep-22	Corn	Europe	Brazil	European importers washed out of corn contracts to switch to Ukraine corn	(Belikova 2022b)

Table 2.2. Examples of Washouts and Origin Switching (continued)

Date	Commodity	Buyer	Seller	Details	Reference
Jul-22	Soybeans	China	U.S.	Three Gulf and Two PNW contracts shifted to Brazil (U.S. "way more expensive than South American counterpart")	(Tinti 2022a)
Jun-22	Wheat	Vietnam	Australia	Vietnam washed out of wheat cargo due to weak demand in the importing country	(Belikova 2022a)
Feb-22	Soybeans	China	Brazil	China washed out of at least 5 cargoes due to negative crush margins in China, some contracts may have switched to US due to slow loading times in Brazil.	(Tinti and Chen 2022)
Sep-21	Soybeans	China	U.S.	Due to Hurricane Ida causing logistical issues, China cancelled cargoes. Some of these cancellations may have been Cargill shifting from US to Brazilian export origins.	(Tinti and Chen 2021a; Chen 2021)
Sep-21	Corn	China	Ukraine	Chinese port congestion led to washouts of corn cargoes set to be imported into the country	(Belikova and Chen 2021)
Jul-21	Corn	-	Brazil	Brazil washed out of export contracts to redirect bushels to domestic markets (premium over export prices)	(Mano and Figueiredo 2021)
May-21	Soybeans	China	U.S.	China washed out contracts totalling close to 2 mmt and switched to Brazil or rolled to US New Crop.	(Tinti and Chen 2021a)
May-21	Soybeans	Mexico	U.S.	Mexico washed out contracts totalling close to 1 mmt and switched to Brazil.	(Tinti and Chen 2021b)

Table 2.2. Examples of Washouts and Origin Switching (continued)

Date	Commodity	Buyer	Seller	Details	Reference
Mar-21	Corn		Brazil	As export basis increased, Brazilian exports feared washouts from their importing counterparts	(Worledge and Belikova 2021)
Mar-21	Wheat		Russia	Buyers of Russian wheat washed out of contracts due to logistical problems with entering the Azov Sea.	(Riabukha and Belikova 2021)
Feb-21	Corn	South Korea	U.S.	South Korean buyer cancelled 132,000 mt and switched volume to cheaper Argentina origins	(Hughes and Belikova 2021)
Aug-20	Soyoil	India	Argentina	India washed out 60,000 mt. Importers shifted to soyoil from Turkey, Russia, and Egypt (closer origins)	(Geyssens 2020)
Oct-18	Soybeans	China	U.S.	U.S. exports slumped due to washouts from China	(Allan 2018)
Oct-18	Corn	Vietnam	Multiple	Buyers considered washouts as demand slowed within the importing country. This included corn sourced from US, South America, and South Africa	(Worledge 2018)

Many washouts have occurred in the 2023 new crop marketing year. In February of 2024, China washed out of April U.S. Gulf Contracts to switch to Argentina for May 2024 execution. At the beginning of the 2023 new crop soybean marketing year, which began in September, as many as 10 US soybean cargos were subject to washout. This came on top of already struggling exports for the United States with the lowest export commitment of recent years. Price competitiveness from South America and logistical woes for U.S. origins were to blame. Brazil had a bumper soybean crop in 2023 allowing them to be more price competitive than the U.S for much longer than typical. During that period, new crop basis for Brazilian soybeans decreased from +0.85 to -1.20, which induced incentive for washouts. Additionally, Argentina's more favorable currency exchange has captured some Chinese demand, detracting from U.S. soybean commitments. Furthermore, low Mississippi river levels presented a challenge for barge traffic heading to the U.S. Gulf export port. Also, the Panama Canal was an issue for Gulf vessels heading to Asian markets as it experienced low draft (Tinti 2023b). These issues were not isolated to the Gulf, as there were also reports of cancelations in September of 2023 from U.S. Pacific Northwest ports. These were likely switched to South American exports due to the strong U.S. dollar and a relatively weaker Brazilian real (Nystrom 2023).

In July of 2022, China "washed out" 5 cargoes booked from U.S. export ports. It was noted that these were settled contractually instead of physically lifted and speculated that the Chinese buyers would be switching to Brazilian ports that were much cheaper (Tinti 2022a). Earlier in the same year, China "washed out" a similar number of Brazilian soybean cargoes. In the article documenting this contract cancellation, HedgePoint Global's Victor Martins is quoted saying, "The arbitrage gains in the futures market more than compensate losses from contract breeches." In this instance, other factors influence the washout as well: China is thought to have switched two of the cargoes to U.S. origins with faster loading pace (Tinti and Chen 2022).

In 2021, Brazil dealt with many washouts relating to contracts for its second corn crop. Corn that was supposed to be exported was instead moved to the domestic market at a premium due to supply shortages in the South American country with large demand from the meat industry for animal feed (Mano and Figueiredo 2021). This period of increased contract default spurred legal action in Brazil resulting in more guidance on washout clauses and contract defaults (Bloomberg 2021).

In 2020, Argentina soybean oil prices crashed after India "washed out" several trades. The reasoning behind this washout was cheaper origins closer to India. As the largest customer of Argentia soy products, this cancellation by India pushed the market lower (Geyssens 2020).

Vietnam washed out of contracts in the Fall of 2018 after demand slowed in the country and they wanted to defer further imports until later months when demand picked up. These washouts affected exporters from the U.S., Argentina, Brazil, and South Africa (Worledge 2018).

In addition to contract washouts, there are also examples involving embedded origin switching options, or optional-origin contract provisions. When the Mississippi river was low in 2022, China reportedly switched optional origin cargoes from U.S. origins to Brazil. These optional origin deals gave China the right to switch origins without having to go through the washout process of cancelling one contract in order to substitute the original contract for one from another origin (Tinti 2022b). This occurred again at the beginning of the 2023 new crop marketing year. China reportedly paid 15 cents premium to have the origin switching option (Jacques 2023). This illustrates the differences between a washout, which involves a cancellation and subsequent origin switch, and an embedded switching option, also called optional-origin provision that is included in the original contract.

2.3.4. Illustrative Examples

To illustrate how washouts and origin switching options work and provide a clear conceptual framework, the following tables have been developed. These illustrate the different mechanisms that drive these interspatial and intertemporal decisions. These examples show spatial switching; however, switching could be similarly applied to switching delivery periods, quality designations, etc. However, we focus on switching between origins.

As is illustrated in Tables 2.3, 2.4, and 2.5, the factor causing switching is changes in the basis at origin 1 and origin 2 relative to each other. In the first example in Table 2.3, the basis of origin 1 doesn't change, but at origin 2 it does. This difference between basis creates switching value and incentivizes the contract washout. In Table 2.4, the basis increased at origin 1 and decreased at origin 2. In Table 2.5, the basis decreases at both origins; however, it decreased by more at origin 2. All three of these situations lead to incentives for the buyer to execute a contract washout and realize positive returns.

Table 2.3. Contract Washout when Origin 1 Basis is Unchanged

Date	**Cash**	**Origin 1 Basis (B_1)**	**Origin 2 Basis (B_2)**	**Switching Value (B_1-B_2)**
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0
T2	Cancel origin 1 contract and switch to origin 2	0	-50	50
T3	Physical receipt of bushels	0	-50	**50**
			Profit:	Φ = +50

Table 2.4. Contract Washout When Origin 1 Basis Strengthens

Date	**Cash**	**Origin 1 Basis (B_1)**	**Origin 2 Basis (B_2)**	**Switching Value (B_1-B_2)**
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0
T2	Cancel origin 1 contract and switch to origin 2	50	-50	100
T3	Physical receipt of bushels	50	-50	100
			Profit:	Φ = +100

Table 2.5. Contract Washout When Basis Weakens

Date	Cash	Origin 1 Basis (B_1)	Origin 2 Basis (B_2)	Switching Value (B_1-B_2)
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0
T2	Cancel origin 1 contract and switch to origin 2	-20	-50	30
T3	Physical receipt of bushels	-20	-50	30
			Profit:	Φ = 10

The return to the washout is calculated as the value of switching minus the cost to switch. This is equal to the switching value (basis in origin 1 minus basis in origin 2) minus the default cost (origin 1 basis at the time of the switch, B_{1T_2}, minus the origin 1 basis at the time the contractual agreement was formed, B_{1T_1}). This is shown in Equation 2.1 below:

$$\phi = (B_1 - B_2) - (B_{1T_2} - B_{1T_1}) \qquad (2.1)$$

In the example in Table 2.3, the profit for the buyer is switching value, which is $0.50. Because the basis at origin 1 didn't change, there is no cost to switch. In Table 2.4, the switching value at T2 is $1.00, as B_2 is $1.00 cheaper than B_1. The cost to cancel the original contract is assumed to be zero, because the basis increased, and the seller could re-sell the grain from origin 1 at a higher price. Thus, the return in Table 2.4 is $1.00. In the example in Table 2.5, the basis at both origins decreased, but origin 2 basis weakened by more than origin 1, which creates switching value equal to $0.30. In this example, the cost of cancelling the contract is $0.20, which is the difference between the basis at origin 1 at T_1 vs T_2. The buyer would realize a return equal to of $0.10.

The mechanics of a switching option are similar. Again, the return is equal to the value from switching minus the cost of switching. However, since the option has been negotiated into the contract, the cost of switching is not the default cost but rather the premium paid for the contractual option. In the following examples, the option is purchased at a premium of 20 cents. The following tables summarize switching mechanics.

Table 2.6. Switching Option When Origin 1 Basis is Unchanged

Date	**Cash**	**Origin 1 Basis (B_1)**	**Origin 2 Basis (B_2)**	**Switching Value (B_1-B_2)**	**Option Premium**
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0	Buy for 20
T2	Execute option to switch from origin 1 to origin 2	0	-50	50	
T3	Physical receipt of bushels	0	-50	50	
				Profit:	Φ = +30

Table 2.7. Switching Option When Origin 1 Strengthens

Date	**Cash**	**Origin 1 Basis (B_1)**	**Origin 2 Basis (B_2)**	**Switching Value (B_1-B_2)**	**Option Premium**
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0	Buy for 20
T2	Execute option to switch from origin 1 to origin 2	30	-50	80	
T3	Physical receipt of bushels	30	-50	80	
				Profit:	Φ = +60

Table 2.8. Switching Option When Basis Weakens

Date	**Cash**	**Origin 1 Basis (B_1)**	**Origin 2 Basis (B_2)**	**Switching Value (B_1-B_2)**	**Option Premium**
T1	Importer buys from origin 1 exporter for delivery at T3	0	50	0	Buy for 20
T2	Execute option to switch from origin 1 to origin 2	-30	-50	20	
T3	Physical receipt of bushels	-30	-50	20	
				Profit:	Φ = 0

As is illustrated in Tables 2.5, 2.6, and 2.7, the major factor deciding whether or not to execute the option is the difference between the original basis and origin 2 (switching value). If the option is executed, then the return generated is equal to the switching value minus the cost of the option (S). This is summarized in Equation 2.2:

$$\phi = (B_1 - B_2) - S \qquad (2.2)$$

In the example in Table 2.6, the switching value (the difference between basis at the two origins) is \$0.50. Since the buyer paid \$0.20 to embed the option in the contract, the return is \$0.30. In table 2.7, the original basis increases while the basis at origin 2 decreases. This creates switching value of \$0.80, and the return net of the \$0.20 premium is \$0.60. In the example in Table 2.8, the basis at both origins weakens, but it decreases by more at origin 2. This creates switching value of \$0.20. The buyer paid \$0.20 to have this option, so their return would be zero.

These examples above provide a framework for understanding the issues addressed in this thesis. The issues have been simplified significantly, and do not consider logistical factors such as freight costs, waiting times, etc. There are many reasons that might incentivize firms to washout and switch or exercise switching options between origins. The chief reason is highlighted above: large intertemporal changes in spatial basis. However, factors such as freight costs, waiting times, end-use margins, geopolitical issues, and politics can also cause these contracting practices. Additionally, while this thesis focuses on switching between origins, the idea of a switching option could be applied to switching between deliver time periods, quality standards, etc.

This study aims to model the option to switch origins in order to derive the value of the flexibility to grain buyers. Additionally, it is examined how this value should be shared between contracting parties in terms of an option premium. This option can be modeled as a real option. Real options have been used as a technique to value assets. There are many traditional valuation methods for different types of assets, such as discounted cash flows (DCF). However, with many assets, there are networks that provide optionality that DCF fails to account for. In order to properly value the investment in assets that provide optionality, a more advanced valuation method must be used. Real options have been utilized in many studies to accomplish this purpose. This methodology is covered more in-depth in Chapter 3.

2.4. Summary

Chapter 2 provides an in-depth exploration of the grain trading industry’s evolving landscape, especially relating to the role of globalization in firms’ pursuits of a competitive advantage. Large firms with geographically diverse footprints take advantage of intertemporal and interspatial price differentials. These spatial arbitrage opportunities have been becoming more prevalent as volatility in commodity prices and freight logistics increases. To capture the value of these opportunities as they arise, washouts are being used more frequently to cancel previous contracts and switch from a higher price origin to a lower price origin. Another way firms could switch origins is through a contractual switching option. These practices are the topic of this thesis.

In the face of a changing commodity trading landscape, firms must adapt to maintain or build their competitive advantage. A common strategy used is to build economies of size and scale. This allows firms to realize cost advantages from more efficient production, logistics, or distribution. This goal can be accomplished through internal development and growth, mergers and acquisitions, or strategic joint ventures. The need to build economies of size and scale is a by-product of an increasing globalized world economy.

Globalization has impacted the entire economy, including the grain trading industry. Global supply and demand forces have dramatic effects on domestic agricultural prices. The emergence of South American counties as major agricultural commodity producers has impacted commodity flows worldwide. This has been demonstrated with major importers such as China demonstrating a preference toward South American grain for a large portion of each trading year (Scheresky 2021). The global interdependence created by increased global trade has created opportunities and challenges for commodity traders, with changes in one region affecting international futures prices and basis levels.

Futures and basis prices for commodities are influenced by various factors, including macroeconomic influences, geopolitical news, production influences including weather, and demand dynamics which can include consumption trends and politics. Despite the many influences on prices, Irwin and Good suggest that commodity price levels are generally mean-reverting, meaning that over time prices tend to be stable (Good and Irwin 2023). However, in the intermediate, there is large variation around these mean prices. This volatility in commodity markets creates opportunities for trading firms to take advantage of.

In addition to commodity prices, logistic costs have become increasingly volatile. For international trade, the most important logistic cost is ocean freight rates. Prices for ocean vessels are volatile because of many factors such as navigation challenges, wars, pandemics, and politics. Uncertain logistic costs add another risk for commodity trading firms to manage, but this volatility can also create opportunities for profit from spatial arbitrage.

Capitalization on price differentials is only possible if firms can switch between origins. In light of increasing spatial arbitrage opportunities, firms have been utilizing washouts and switching options in contracts to move between origins. Washouts occur when buyers cancel a contract. This gives them the option to enter into a new purchase agreement from a different origin. A switching option gives the buyer of the original contract the right to switch origins in exchange for the payment of a premium.

There is a plethora of industry examples where buyers use washouts and switching options. Grain buying organizations for countries like China, Egypt, and Vietnam have washed out of contracts and switched origins due to factors like price competitiveness, quality considerations, logistics, and politics. These examples occur more frequently for commodities of a more homogenous nature, such as corn and soybeans. While many of these washouts and origin switches are negotiated outside of the contractual agreement, some switches are options built into a contract provision. It is foreseeable that more embedded contractual switching options will be used in the future in international grain trading contracts.

Previous academic studies have investigated grain contracting provisions, counter-party risks, and contractually optionality. Real option valuation has been used in some of these previous works, including those applied to the commodity trading industry. Real options are used to value assets with embedded flexibility. This is the topic of the following chapter.

Washouts are common in the grain trading industry. With this mechanism, buyers are able to exit their obligations to a seller. Then, they can replace their current contract with one from a lower cost origin. This cancellation and subsequent switch has become a prolific practice in industry trade. The strategic management of this mechanism on the part of both buyers and sellers is important for success. One solution may be the embedded switching option, which is written into the original contract and allows grain sellers to provide optionality to buyers so they don't have to default on their contracts and can rather execute the option, based on the privilege they purchased in exchange for the option premium.

This chapter explored the industry dynamics that lead to the topic of study in the thesis. Previous studies were examined in order to provide background relating to this study. Most pertinently, this chapter establishes the importance of optionality in contracts, which lays the groundwork for the research conducted in subsequent chapters.

3. REAL OPTION METHODOLOGY

The problem this thesis is addressing is contract washouts and origin switching in international grain contracts. As highlighted in Chapter 2, this is becoming a common industry practice. The underlying issue here is that contemporary contracting practices involve flexibility and optionality. In order to model this problem, real option methodology is used.

This chapter provides the conceptual framework for real option methodology. After the problem is framed conceptually, the chapter discusses different techniques for the valuation of real options. Finally, previous studies that have utilized real option methodologies are discussed in order to provide a background of understanding for how this problem relates to the rest of the literature. Real option methodology provides a powerful tool to help understand and value both ex-post contract washouts and switching options embedded in the original contract.

3.1. Relation to Washouts and Origin Switching

Meersman et. al claimed that the most successful commodity trading firms are those who are masters of optionality (Meersman et al. 2012). For firms in the grain trading industry, there are many different decisions to make each day and strategic variables to be managed. This includes managing many different assets, ranging from human capital and labor to facilities and logistics. These assets provide flexibility for managers and allow them to navigate changing market conditions and industry evolutions.

As supply chain managers, grain trading firms must also manage their grain contracting strategies. These companies move grain around the world, taking it from producers to consumers. As masters of optionality, they have the ability to originate grain from multiple geographic locations. Similarly, they must master the optionality that they provide in contracts. As buyers and sellers of grain, they have many different types of contracts that they can use to govern their interactions with other related parties. These contracts are assets that provide the firms value. Just like physical assets that firms manage, many of these contracts are also embedded with flexibility that provide value.

As discussed in Chapter 2, some market participants demand optionality within their grain contracting strategies. Grain buyers and sellers enter into contracts to move grain around the world, but they desire flexibility to manage these contractual obligations. This has given rise to what is colloquially known as washouts. This contracting strategy involves defaulting on a previous contractual obligation in order to participate in a more favorable market. Buyers looking to switch from a higher cost origin to a cheaper one may resort to a washout.

Traders may also seek to use contractual clauses that provide the optionality desired by market participants. A switching option negotiated ex ante into the contract can be used to give the buyer the right to switch grain origins at a later time in exchange for the payment of a premium. This type of contracting strategy also provides flexibility for firms to manage. This study focuses on switching origins in grain contracts; however, there could be other options in a grain contract to provide flexibility. This could include switching between grain qualities or between different delivery periods.

Clearly, these contracting strategies are all about flexibility. Real options can be used to value flexibility. The technique of real option valuation allows for the quantification of managerial optionality and strategic interactions. For firms to become the masters of optionality, they must first be able to quantify the value derived from the optionality; in this case specifically related to the ability to washout contracts and switch origins.

3.2. Introduction to Real Options

3.2.1. Real vs Financial Options

Real options are related to and built on financial options. Real options borrow many of their conceptual constructs from financial derivatives. This includes option type, exercise, maturity, and valuation. The main difference is that real options take the financial option framework and apply it beyond financial securities and derivatives to physical assets and asset valuation.

An option gives the holder the right, but not the obligation, to buy or sell an underlying asset. For financial options, the underlying asset is a marketable security. Conversely, real options account for the flexibility imbedded within physical assets. In the case of this thesis, the real option accounts for the flexibility of a buyer of grain to switch the origin of grain in their purchase agreement to a lower-cost market.

For financial options, calls grant the purchaser the right, but not the obligation, to buy the underlying asset. Puts give the holder of the option the right to sell the underlying asset. This right does not last indefinitely, rather it exists only until the time of expiration of the option. This is referred to as the expiration date, and it is the day after which the option to exercise is no longer available for the purchaser of the option. For financial options, the purchaser of the option must pay the writer (seller) of the option a premium in order to assume the rights of the option. These elements are also used in the real option framework.

There are also different types of options based on when the option can be exercised. These include American, European, Bermudan, and Asian styles, among others. European options may only be exercised on the expiration date. American options, which are most common in commodity futures exchanges, may be exercised on any trading day on or before expiration. Bermudan options may be exercised only on specific dates on or before expiration. Asian options have a payoff determined by the average price of the underlying asset during some pre-determined time period (Johansen 2013). Real options are also modeled with different option styles.

Options are priced based on different factors. Those directly impacting the price of options on futures are the futures price, option strike price, time to expiration, the volatility of the futures price, and short-term interest rates. The value from an option comes from both its intrinsic value, which is the difference between the price of the underlying futures price and the option's strike price, and the extrinsic value, which is the time value and determined by volatility of the futures contact and the time remaining to expiration (IFM 2022).

As discussed by Schwartz and Trigeorgis, the option pricing theory which developed in the 1970s was based on pricing securities by arbitrage methods. This involves using a risk-neutral framework to estimate the option value where the rate of return on investment of the option and underlying asset is equal to the risk-free rate of return. This approach is based on the idea that options can be replicated synthetically, and their value is derived from the value of the underlying assets. The expected value of the assets rate of return at maturity is discounted back to find the current value (Schwartz and Trigeorgis 2004).

Real option valuation uses this same risk-neutral framework to value investments in different assets. The advantages include accounting for all the flexibilities of the asset, using all the information from the market prices, and determining the value of the investment and optimal operating policy (Schwartz and Trigeorgis 2004). This is the starting point for real option valuation.

3.2.2. Discounted Cash Flow vs. Real Options

Real options have been proposed as the best methodology for valuing assets with embedded flexibility. However, it is worth examining other methods, which document the rise in popularity of real option valuation in financial literature. The most commonly used approach prior to the evolution of real option valuation was discounted cash flows (DCF). This method seeks to determine the value of an asset based on its future cash flows. This involves using a discount rate to find the present value of those future cash flows, using net present value (NPV). This method has serious limitations, especially related to the type of problems faced by those in the business world who are managing uncertainty over many periods of time.

Real options present a method that accounts for all available information, even information that is yet to be revealed over time. The discounted cash flow (DCF) method uses only what is known at time period 0, so it implicitly assumes that management is committed to the same decision over time, even as relevant variables may change the most optimal decision. This causes the failure of discounted cash flows to value important factors like the managerial flexibility, new opportunities, and uncertainty about future cash flows (Alizadeh and Nomikos 2009). This is not to say that real options are a substitute for DCF. Rather, ROV should be seen as a supplement to DCF (Kodukula and Papudesu 2006). Real options should be used whenever the process of decision making takes place over a series of time (Guthrie 2009). That is why this thesis uses real option valuation for the problem presented.

3.2.3. Forms of Real Options

There are many different classifications of real options, each of which is used to model different situations. The different forms of options are used as framework for various kinds of flexibility provided in assets that the valuation technique is applied to. As Amram and Kulatilaka say, the real options framework is applicable to many situations in many industries, although each application has to be tailored to the specific industry and market (Amram and Kulatilaka 1999). The different forms include the abandonment, barrier, expansion, chooser, contraction, deferment, and switching option. These different real options have been summarized in Table 3.1.

Table 3.1. Forms of Real Options

Real Option Type	Description
Abandonment	Provides the option to abandon current operations permanently and realize the resale value of the asset.
Barrier	Provides the flexibility to execute an option once a barrier is breached.
Chooser	Provides the flexibility to choose between different strategies.
Contraction	Provides the option to outsource operations.
Deferment	Provides the option to wait x amount of time in order to observe changing market conditions before deciding on a course of action.
Expansion	Provides the option to expand the scale of operations.
Sequential Compound	Options in which the value of strategic options depend on previous options in the sequence. This involves phased investment.
Switching Option	Provides the option to switch between inputs, outputs, markets, technologies, or other assets.

Source: Trigeorgis (1999)

The appropriate real option form depends on the application. In order to find the best framework for the problem at hand, decision makers must consider the assets they are trying to value and what types of flexibility and optionality are embedded within.

3.2.4. The Choice Option Framework

There are several different real option frameworks that could be chosen to model the problem presented in this thesis. The embedded switching option, which is written into a contract, is modeled as a switching real option form. This is the obvious choice, as the name implies. The definition of the switching type real option refers to switching between to states, whether it be two states of operation or in this case two states of contractual obligation, with the difference between the states being their geographical origin.

The strategic default, called a washout, could be modeled in a few different ways. Based solely on the definition of default, it could be framed as an abandonment option. Based on the definition of the abandonment type real option, the grain buyer could either keep their asset, the contract for purchase of grain, or abandon it for its salvage value, which equates to defaulting on the contract and settling it financially rather than physically. However, if we include the idea of strategic default with the assumption of switching the origins as a subsequent event, it could be framed as a switching option. A third potential choice is the sequential compound option, which frames a washout as a series of options, where first the decision maker has the option to abandon, or cancel, their original contract, which then creates the option to switch to another origin. The use of the sequential compound real option framework presents the best way to value a washout option as it is inclusive of all the optionality of a washout. Furthermore, it provides a broader framework that is better fit for a term that is equivocal.

Both the embedded contract provision and ex post washout negotiation involve options that are executable over an entire period of time. For this reason, the options are framed as American type. Additionally, both the switching and abandonment options are framed as puts. After deciding on the proper framework for the real option, the next step is to determine the appropriate method of calculation for the model.

3.3. Real Option Valuation

Real options can be valued using different methods, and some methods are more suitable for certain types of problems and option frameworks. The choice method often depends on the specifics of problem and balancing desired levels of accuracy and efficiency (Trigeorgis 1999). According to Amram and Kulatilaka, there are three general solution methods: analytical solutions, dynamic programing approaches, and simulation methods (Amram and Kulatilaka 1999). Bullock et. al (2019) uses four categories of calculation approaches: closed form option formulas, Monte Carlo simulation, lattices, and decision trees. A brief discussion of each of these calculation methods follows.

3.3.1. Closed Form Option Formulas

Some real options can be valued using an analytical approach that solves a partial differential equation. In order to do this, the option must be mathematically expressed with a differentiable equation with boundary conditions. The most commonly used closed-form option formula is the Black-Scholes equation, which values options with a European style settlement (Amram and Kulatilaka 1999). Sometimes, exact numeric solutions are not possible to find; rather, numerical approximations can be used to give a solution for the option value. Overall, there are advantages to using a closed form option formula; however, it is often impractical to exactly define a mathematical equation in order to calculate the option value. This has led to other methods of real option valuation.

3.3.2. Monte Carlo Simulation

Simulation models are another method of option value calculation. The most commonly used simulation method is Monte Carlo simulation. Using simulation, many different possible results are calculated to model potential evolution from the present to the future. The payoff of each iteration is calculated. Then the payoffs are averaged over the number of iterations and the value is discounted back to the present time in order to arrive at an option value. Monte Carlo can model many real-world applications and has more computational power than some of the other methods. Simulation methods are better suited for European type options, and do not work as well for American options with flexible exercise.

3.3.3. Lattices

Real Option Valuation can also be calculated with lattices. This method involves laying out the evolution of possible values of the asset from the current time until the option expires. This results in an outlay of values whose path from the current time to the future resembles branches of a tree. To solve for the value of the option, the values of the different possible branches are folded recursively backward. This allows the method to arrive at the value of the option (Kodukula and Papudesu 2006).

There are different types of lattices, including binomial, trinomial, and multinomial. Furthermore, lattices can be both recombining (closed) or nonrecombining (open). The most commonly used formation for real option valuation is the recombining binomial lattice. This formation assumes that starting at the first time period the value can move either up or down. This continues in subsequent periods. The lattice is recombining if the value of branch that went up and then down is equal to that which went down and then up and also equal to the starting value (Razgaitis 2003).

Lattices are more flexible than both closed form equations and simulations, so they are better suited for option types with variably exercise dates (Bermudan or American options). It is flexibility that Kodukula and Papudesu cite as the reason the recombining binomial lattice is the preferred method for most practitioners. They argue that the framework of the lattice is more transparent and its solution a close approximation of the option value that is most accurately calculated with option formulas (Kodukula and Papudesu 2006). A related method involves using decision trees, which offer many of the same benefits.

3.3.4. Decisions Trees

Decision trees create a strategic road map that includes different decision points and their returns or costs. These decisions are based on observed events and their probabilities of occurrence. Decision Tree Analysis (DTA) builds upon other real option valuation methods in order to incorporate uncertainty from sources private and specific to a firm, as opposed to other methods which only explain market risk. Decision trees do have drawbacks. The probabilities of events occurring within the decision tree are subjective. Additionally, there is not concrete guidance around the discount rate that is used to fold back values from the decision tree to the present time (Kodukula and Papudesu 2006). Nonetheless, integrating decision trees into other real option valuation methods allows for the consideration of both market and private risks.

3.3.5. The Choice Valuation Model

For the problem addressed in this thesis, a lattice is utilized. This is for a couple of reasons. With American type options, lattices and decisions trees are the better valuation models. The sources of volatility that create option value are market driven processes, which suggests the use of a lattice. However, the markets driving this volatility are highly correlated, which can present issues for valuation with a lattice. Because of this, the traditional use of the binomial lattice is modified in order to account for correlation. This is accomplished by incorporating @Risk distributions with correlation matrices into the lattice.

Using lattices, dynamic programming, and incorporating @Risk distributions with correlation matrices is a way to solve both the switching-type real option and the abandonment and compound type real options. The general switching-type real option is solved in a series of steps. First, build a decision tree to define problem-states and the allowable transitions between project states. Second, a lattice is built for the state variable. Next, build a lattice for the market value of the project for each possible state. This step involves first defining the value of the terminal node in each separate state. Then, recursively fill in the rest of the tree working backwards from the terminal node. This recursive process is accomplished using the following equation:

$$V_m(i,n) = \max_{j \in J_m} \left\{ Y_{m,j}(i,n) + \frac{\pi_u(i,n)V_j(i,n+1) + \pi_d(i,n)V_j(i+1,n+1)}{R_f} \right\}, \qquad (3.1)$$

where V_m is the value of the project in state m at node (i,n). In the lattice, nodes are notated with time periods n as columns and down-moves i as rows. The project can switch between project states j, which are an element of the allowable transitions denoted as J_m. $Y_{m,j}$ is the cash-flow in the current period from switching. This is added to the future value of the project in state m,j, which is discounted using probabilities of an up and down moves in the lattice, π_u and π_d, and the one-period risk free interest rate, r_f (i.e., $R_f = 1 + r_f$). Using these general steps, the value of the switching-type option can be found.

The compound real option is valued using recombining binomial lattices and dynamic programming in a similar manner. The main difference is the there are two valuation lattices, represent the two options that exist. The type of compound option in this thesis is a sequential compound option, meaning that the second option only becomes available after the first option is exercised. To derive the value of the compound option, begin by building the projection lattice for the state variable. Then, proceed to the market valuation lattices. Begin with the terminal nodes, using the appropriate equation to value the option at the end of optionality period. Next, start with the second option valuation lattice, which is the switching option. This tree is built in the same manner as in Equation 3.1. Once the switching option lattice is built, proceed to the first option, which is an abandonment option. In this lattice, the decision maker either can wait and continue in their contracted state or abandon their contract in order to have the switching option become available. Equation 3.2 is used to recursively value the option in the valuation lattice.

$$V_2(i,n) = Max\begin{Bmatrix} \frac{\pi_u(i,n)V_2(i,n+1)+\pi_d(i,n)V_2(i+1,n+1)}{R_f}, \\ -J_1 + \frac{\pi_u(i,n)V_1(i,n+1)+\pi_d(i,n)V_1(i+1,n+1)}{R_f} \end{Bmatrix} \quad (3.2)$$

This gives us the value of the compound option. In this equation, V_1 is the value of the switching option, V_2 is the value of the abandonment option, and J_1 is the cost of abandonment (Guthrie 2009). Using this framework, a washout can be valued.

The specifics of the data and the model are expanded upon in subsequent chapters. The remainder of this chapter examines at how real options have been utilized to study related problems in order to justify its use in modeling washouts and contractual origin switching options.

3.4. Previous Studies

Real option valuation has been the topic of many academic studies and used in many different industry applications. Many scholars have used the advantages of the methodology to solve contemporary issues in finance, including asset valuation, resource allocation, strategic interaction, and other decision-making problems. A discussion of the pertinent studies is included below which summarizes the studies using real options related to commodity trading and contract optionality.

Trigeorgis (1999) summarized the development of real options as a method of valuation. He credits the seminal work in pricing financial options by Black and Scholes (1973) and Merton (1973) as the building blocks for where the literature has come. Applying option valuation to investments allows managerial operating flexibility and strategic interactions to be captured. Real options have been used for over 35 years in financial literature. The first applications came in natural resource investments, but these applications have expanded to include investments such as research and development, company valuation, mergers and acquisitions, intangible asset valuation, and others. In fact, Razgaitis (2003) lists many major companies as users of real option valuation, such as Mobile, Exxon, Texaco, Airbus Industries, Apple, and Hewlett-Packard. This highlights the embrace of the business world of this new financial valuation tool.

Adkins and Paxson (2011) studied different solutions to real options involving stochastic inputs and outputs. They apply this to crude oil production, where natural gas is an input with a random cost and there is cost to switch between operating and not operating. Halting operations and subsequently re-starting production have a cost, and the real option provides a valuation for both possibilities. While this study applied to natural gas production, many other facilities were listed that this could be expanded to, such as soybean processing and ethanol plants. Additionally, it was suggested that this methodology could be extended to distribution and transportation activities.

In another application of this methodology, Dockendorf and Paxson (2013) illustrated a switching option for a fertilizer plant that can switch between producing ammonia and urea. The study results indicated that even though these two output commodities were highly correlated, there is value in having the flexibility to switch between the two. While the ability to switch is more valuable with assets that are less correlated, there is still observed value from being able to switch with assets that are correlated to a higher degree. This can be especially true in more volatile commodity markets. Another result from this study indicated that the switching boundaries, where the option to change outputs is exercised, narrow as the prices of the outputs decline.

Real option valuation has been used to model situations involving optionality for commodity trading firms. Johansen and Wilson (2019) used real options to value a firm's geographical diversification, which gives firms embedded flexibility in their trading network. They showed that commodity trading firms can derive value from being able to switch origins in export trade. This is due to the flexibility the firm retains when they include the option to switch. They further derive the determinates of this value as the margin distributions from the different origins and the correlations among these distributions. As correlation between the prices at different origins increases, the value of the real option decreases. This is because higher correlation equates to less arbitrage opportunities for firms to take advantage of. This means that as markets become more integrated, that is to say correlated, a geographically diverse firm loses its competitive advantage. This highlights the benefit of market inefficiencies to large trading companies.

Hanson used real options to value origin type switching options, which he defines as the option allowing the seller of grain to physically fulfill the contract with grain from any of the negotiated origins at the cost of the premium settled upon in the contract. These options are a way for grain trading firms to take advantage of spatial arbitrage opportunities. With this type of option, sellers can source grain from their least cost origin to fulfill their contractual obligations. The value of the optionality is shared between the buyer and seller in the form of the premium paid. The premium is equal to a percentage of the option value. In Hanson's study, he shows how the profitability of contracting with switching optionality changes as the premium as a percentage of the option value changes. With 50% of the option value being shared between the buyer and seller, the option is still profitable around two thirds of the time. Building on the work of Wilson and Johansen, he further studies how correlations among the price differentials between origins affect the origin-type switching option. Additionally, sensitivities are conducted on the number of potential origins to switch between, the time period used to calculate the option value, the exclusion of freight as a variable driving option value, and different types of options used in the real option valuation (Hanson 2020).

Real option valuation is a powerful tool that has evolved in the financial literature and one that can be applied to model a broad range of problems in many different industries. For this thesis, the methodology helps us to frame the flexibility and optionality decisions related to washouts and origin switching contracts and derive the value of these contract provisions.

3.5. Summary

Real option valuation is a powerful modeling tool that allows for the assessment of managerial flexibility and strategic interactions. This approach developed in financial literature and has been applied to many different industries through a variety of studies. This includes applications to businesses of all types for the valuation of physical assets, research and development projects, company valuation, mergers and acquisitions, and intangible asset valuation. The ability to account for the value of imbedded flexibility and optionality is what makes real option methodology appealing to this study.

One of the first steps in using real options to value assets is to establish a conceptual framework. This involves drawing parallels to financial options to frame the application in the context of options. Thus, real options are framed as puts or calls, with different types of expiration such as European and American. Additionally, there are different types of real options, each of which involves a different type of managerial flexibility.

There are multiple methods for valuing real options. This includes closed-form formulas, Monte Carlo simulation, and lattices. Additionally, decision trees can be utilized in some situations to frame and value real options. There are situations suited to each of these different methods based on the problem and the framework.

Recent studies have shown the applicability of real options to different industries. In the commodity trading industry, ROV has been used to value an option to switch between different outputs in a fertilizer production plant. Additionally, real options were used to value the flexibility of switching the origin of grain in international trade, at the option of the seller.

For this study, real options are used to value the flexibility of origin switching at the option of the buyer. Contract washouts and contractual switching options are valued using a switching type real option with American type expiration. The value of the option is computed using elements of a recombining lattice. The details of this calculation are provided in the following chapters.

4. EMPIRICAL MODEL

4.1. Introduction

To illustrate the issue central to this thesis, two models are developed: one for embedded origin switching options and another for contract washouts. Further, the model is applied separately to corn and soybean price data. These models are built for a representative Chinese grain buying firm sourcing grain from the cheapest origin. In the corn application, the buyer has five origins they consider: U.S. Gulf (USG), U.S. Pacific Northwest (PNW), Brazil (BRZ), Argentina (ARG), and Ukraine (UKR). The model assumes that the firm contracts with a seller through the USG but examines how valuable the ability to washout of the contract is. The other model determines the mean value of an embedded origin switching option written into the contract which gives the firm the option to switch from the USG to other origins available. This contract is made available to the Chinese buyers by a multi-national grain trading firm with a diverse footprint and the ability to source grain from any of the five potential origins. The soybean application is nearly identical, except a Ukraine origin is not considered.

This chapter develops the details of the model explained above. It begins with a discussion of the set-up of the model, including the base case assumptions and planned sensitivity analyses. Then, the chapter delves into the model's logic and mathematical equations. Finally, an in-depth exploration of the data and distributions is provided. This introduction to the model serves as a prerequisite to understanding the results and conclusions presented in subsequent chapters.

4.2. Model Specification

This model makes use of real option methodology to value the topic of the thesis: contract washouts and embedded origin switching options. The theoretical background and previous studies using these techniques are explored in Chapter 3. The focus of this chapter is the application of these methodologies in building this model.

4.2.1. Base Case Assumptions

This study analyzes embedded origin switching options and contract washouts. Embedded origin switching options occur when a buyer and seller embed the option to switch origins in the original contract. Alternatively, contract washouts occur when buyers execute contract cancellations, which allows them to subsequently switch the origin of their grain.

The models are specified similarly when using corn and soybean price data, with one important distinction. The models using soybean prices include the U.S. Gulf, U.S. Pacific Northwest, Brazil, and Argentina as potential grain origins. The models using corn prices include all of these with the addition of Ukraine, which is an important competitor for Chinese corn import demand. All other model specifications are identical. To conduct analysis and provide a basis for comparison, a base case is defined for these models. The base case is meant to be a situation most representative of industry practices regarding these contracting provisions. Both the embedded origin switching option and the contract washout models are run using two different periods of data, due to a structural break in the dataset which resulted in different representative distributions. Thus, the two periods are pre- and post- structural break.

4.2.1.1. Embedded Origin Switching Option Base Case

The base case for the embedded origin switching option model is a Chinese buyer who has contracted to buy grain to be shipped from the U.S. Gulf. In their contract, they negotiated an origin switching option that allows them to change origins. This optionality exists until the grain is to be shipped, which is in five weeks in the base case. In the base case, price volatility at each origin and correlation between the two is set equal to historical calculations.

4.2.1.2. Contract Washout Base Case

The base case for the contract washout is defined very similar to the embedded origin switching option base case. A Chinese buyer has contracted to buy grain shipped from the U.S. Gulf. After the contract has been consummated, but not executed, the buyer has options. First, they have the option to abandon their contract, settling contractually rather than with physical delivery. If this option is exercised, then the buyer has the option to switch their intended purchase of grain to an alternate origin. Again, this optionality exists for five weeks in the base case.

4.2.2. Model Structure

This model uses recombining binomial lattices to value contract washouts and embedded origin switching options framed as compound abandonment and switching real options, respectively. The basis of a recombining binomial lattice is a tree of values of the state variable that could occur based on a series of up or down moves in the value of the state variable. This is shown in Table 4.1, which tracks the value of an asset, starting with its initial value V_0. The potential value of the asset is tracked throughout the tree based on the number of time periods n that have passed and the number of down moves i that have occurred. The assumption is built on the volatility of the variable remaining constant throughout the lattice moving forward. This is the first step in setting up the model.

Table 4.1. Recombining Binomial Lattice

	Time Periods (n)						
Down-moves (i)	(i,n)	0	1	2	3	…	n
	0	V_0	V_0u	V_0u^2	V_0u^3	…	V_0u^n
	1		V_0d	V_0ud	V_0u^2d	…	$V_0u^{n-1}d^1$
	2			V_0d^2	V_0ud^2	…	$V_0u^{n-2}d^2$
	3				V_0d^3	…	$V_0u^{n-3}d^3$
	…					…	…
	i						$V_0u^{n-i}d^i$

Next, another lattice is built to track the potential market value of the contract practices in different states, given the allowable switches between project states. This step makes use of recursive dynamic programming. It begins with the terminal node, or the value at the end of the option lifetime. Then, the lattice uses arbitrage free pricing theory to account for the future value of nodes. This backward induction continues until a value is derived for the current period that represents all current and future value of the asset. The equations used for this step differ based on the framework of the real option. The logic behind these model specifications drives the mathematical equations used.

4.2.2.1. Model Logic

These models are built to model two similar, yet distinct, contracting practices. Thus, there is similar logic driving the model specifications for both the embedded origin switching option and the contract washout. However, because of the distinctions, the logic is presented separately.

4.2.2.1.1. Embedded Origin Switching Option Model Logic

This model represents a Chinese buyer who has contracted to buy grain via the U.S. Gulf. In the case of the embedded origin switching option, the buyer has negotiated a clause into the contract that allows them to switch the origin of their grain at any time during a 5-week period.

In order to model this, the U.S. Gulf grain price is specified as the state variable. Using a projection lattice, this price is projected forward from its current value using a series of up and down moves. The size of these moves is based on the historical volatility of U.S. Gulf prices. This projection lattice is used in valuing the contract with the switching option. To accomplish this, a valuation lattice is built. This lattice models the decisions that the grain buyer makes throughout the period that the optionality exists. As the lattice moves through each period n, the decision maker chooses to either switch to another origin or to keep their contract as is with the grain sourced from the U.S. Gulf. The option to stay at the U.S. Gulf is discounted backwards. To derive the value of the switching option, the value of the contract with the switching option is compared to the value of a contract without such optionality.

4.2.2.1.2. Contract Washout Model Logic

This model also represents a grain buyer who has contracted to buy grain from the U.S. Gulf. However, in this case the contract does not provide any provision for switching origins. Thus, if the buyer wishes to change origins, they must washout their contract. This is modeled as first abandoning their contract, which opens them up to the option to choose the lowest-cost origin. This is why the washout is modeled as a compound sequential option, with the option to abandon or cancel the contract existing first. If that option is exercised it creates the option to switch between different origins. To model this industry practice, the U.S. Gulf price is selected as the state variable. Similar to the embedded origin switching option model, the U.S. Gulf price is projected forward in the projection lattice.

Next, two valuation lattices are created: one for each option in the compound option. The option to abandon allows the Chinese buyer to choose between remaining in the contract at the U.S. Gulf or defaulting on their contract to allow themselves to switch to any other origin. The value of remaining in the contract is discounted to the present node. The value of abandoning is determined by the second valuation lattice, plus the cost of abandoning. To default, the buyer must pay the difference between the current price at the Gulf and their contracted price. The second lattice determines the minimum price available at different geographical origins. Again, the decision maker can choose the minimum, or wait another period to re-contract. The value of waiting is discounted to the present as well. Again, the value of the washout is isolated by subtracting the contract washout value from the value of a contract where there is no possibility of washout.

The logic of these models drives the equations used to build the valuation lattices. These mathematical specifications are given in the next section.

4.2.2.2. Mathematical Specifications

Contract washouts and embedded origin switching options make use of compound abandonment and switching real option frameworks, respectively. The valuation of the real option using a binomial lattice varies based on the option framework. The projection lattice is the same for both types of real options. This projection lattice, *X(i,n)*, shows how the state variable, the CNF price of grain at the U.S. Gulf, could evolve. This is based on a series of up and down moves. The values of the up (u) and down (d) steps are calculated as follows:

$$u = e^{\sigma\delta}, \tag{4.1}$$

$$d = -e^{\sigma\delta}, \tag{4.2}$$

where σ is the historical volatility of USG prices, and δ is used to transform different time periods.

After building the projection lattice for the state variable, the valuation lattice can be constructed. The equations used to value these lattices differ between the switching real option framework used to value the embedded origin switching option and the compound real option framework used to value the contract washout.

4.2.2.2.1. Switching Type Real Option: Embedded Origin Switching Option Valuation Equations

Building the market valuation lattice begins by valuing the terminal nodes of the lattice. For the switching real option, the value at the terminal node, *V(i,5)* is determined as follows:

$$V(i,5) = Min(USG_0, PNW_5, BRZ_5, ARG_5, UKR_5), \tag{4.3}$$

which returns the minimum price available between the contract price and the price at period 5 at the other origins that the grain buyer is allowed to switch to per the contract.

After valuing the terminal nodes, backward induction is used to recursively value the switching option. Use the following equation to work backwards in the lattice from right to left:

$$V(i,n) = Min[\frac{\pi_u * V(i,n+1) + \pi_d * V(i+1,n+1)}{R_f}, \quad Min(PNW_n, BRZ_n, ARG_n, UKR_n)], \tag{4.4}$$

where π_u and π_d are the probability of an up-step and down-step, respectively, in the projection lattice. R_f is the one-period risk-free interest rate. Using this equation, the value of the contract with the option to switch is derived, which is compared to the value of a contract with no optionality to find the value of the embedded origin switching option.

4.2.2.2.2. Compound Real Option: Contract Washout Valuation Equations

The compound real option, used to value a contract washout, uses many of the same constructs as the switching real option framework. The projection lattice for the state variable, the U.S. Gulf price, is built using the same equations (Equations 4.1 and 4.2). The differences arise in building the valuation lattices. This compound option includes first the option to abandon the original contract, which if exercised creates the option to switch to any origin. Thus, there are two valuation lattices used—one for each individual real option.

First, the valuation lattice for the switching option is constructed. This is done in the same manner as above for the embedded origin switching type option, with minor adjustments. Begin at the terminal nodes and use the following:

$$V_1(i,5) = Min(USG_5, PNW_5, BRZ_5, ARG_5, UKR_5), \quad (4.3')$$

which is the same as Equation 4.3, except it allows the decision maker to choose the current price (period 5) at the U.S. Gulf instead of the USG contracted price.

Once the terminal nodes are calculated, dynamic programming equations are used to recursively solve the rest of the lattice. Again, the equation for this lattice is similar to the one used for the embedded origin switching option, with the addition of the option for the decision make to choose the current price of the USG. The following equation is used to solve the first valuation lattice, V_1, in the compound option:

$$V_1(i,n) = Min[\frac{\pi_u * V(i,n+1) + \pi_d * V(i+1,n+1)}{R_f}, \quad (4.4')$$

$$Min(USG_n, PNW_n, BRZ_n, ARG_n, UKR_n)].$$

However, there is a second lattice, V_2, used to model the abandonment option. At the terminal nodes of this lattice, $V_2\ (i,5)$, the following equations are used for the calculations:

$$V_2(i,5) = Min(USG\ Contract, V_1(i,5) + S), \quad (4.5)$$

$$S(i,n) = Max(USG\ Contract - X(i,n), 0), \quad (4.5a)$$

$$V_2(i,n) = Min\begin{bmatrix} \frac{\pi_u(i,n)V_2(i,n+1)+\pi_d(i,n)V_2(i+1,n+1)}{R_f}, \\ \frac{\pi_u(i,n)V_1(i,n+1)+\pi_d(i,n)V_1(i+1,n+1)}{R_f} + S(i,n) \end{bmatrix}. \quad (4.6)$$

Equation 4.6 is used to backwardly induct the values of the abandonment lattice, V_2. This equation returns the minimum value of proceeding to the next period with the contract in place or abandoning the contract, which creates the option to switch origins. However, this is not without cost, so equation 4.5a is added to represent the cost of cancelling the contract. $V_2(0,0)$ represents the value of a contract that can be washed out. This is compared to the value of a contract where no washout potential exists to derive the value of the washout contracting practice.

These mathematical specifications detail how recombining binomial lattices are used to value both types of contracting provisions of interest to this thesis: embedded origin switching options and contract washouts. The results of these models are discussed in the next chapter. The models used for the base cases are altered slightly to conduct sensitivity analysis, as detailed in the next section.

4.2.3. Sensitivity Analysis

Base case data is compared to results obtained by varying key variables. This allows for the demonstration of how different factors relevant to the contracting provisions drive option value. Several different sensitivity analyses are conducted. This includes the time period, volatility, and correlation. The base case and sensitivity analyses are summarized in Table 4.2. The base case, which is 5 weeks with multiple origins and historical volatility and correlation values, is compared to sensitivity analysis results for models using different data sets, separated into corn and soybean prices and pre- and post- structural break, which occurred in June of 2020.

Table 4.2. Base Case and Sensitivity Analysis Specifications

Model		**Corn**		**Soybean**	
Embedded Switching Option		Pre-	Post-	Pre-	Post-
Base Case					
Sensitivities:					
Time (Weeks)	20				
Volatility (σ)	+10%				
	-10%				
Correlation	+10%				
	-10%				
# of Optional Origins					
Contract Washout					
Base Case					
Sensitivities:					
Time (Weeks)	20				
Volatility (σ)	+10%				
	-10%				
Correlation	+10%				
	-10%				

4.2.3.1. Optionality Time Period

The base case assumes that the buyer of grain has five weeks until their optionality expires. In order to analyze how the mean value of this optionality changes with more time until expiry, the time period is extended to 20 weeks.

4.2.3.2. Basis Volatility

Intuitively, the volatility of the basis values is one of the most important factors that leads to profit from switching origins. As the basis levels at different ports change relative to each other, arbitrage opportunities arise and induce washouts and origin switching. To analyze this in the model, the volatility is varied plus 10% and minus 10% from historical values.

4.2.3.3. Origin Correlation Factor

Another intuitively important factor is the correlation among origin prices. Even if there is higher volatility, arbitrage opportunities would not exist if values vary with each other to a high degree. In order to quantify the effect of correlation, the correlation values are increased 10% and also decreased 10% for sensitivity analysis.

4.2.3.4. Number of Optional Origins

When buyers and sellers negotiate the inclusion of an embedded origin switching option in their original contract, there are several terms that would be discussed. One of these is the number of optional origins that the buyer is allowed to switch to. To illustrate how that negotiable variable affects the value of the embedded origin switching option, sensitivity analysis is conducted by reducing the number of optional origins to one.

4.3. Data

These models used data from different geographical export ports. In the models using soybean price data, four geographical export origins were included: the U.S. Gulf (USG), the U.S. Pacific Northwest (PNW), Paranagua, Brazil (BRZ), and Argentina (ARG). The models using corn prices included all four of the previously mentioned ports with the addition of Odessa, Ukraine (UKR). Free-on-board (FOB) prices were used for both corn and soybeans. Freight costs from these export origins to Dalian, China were added to arrive at Cost-and-Freight (CNF) prices. This data was used to calculate the cost of purchasing corn or soybeans from major global export ports for delivery to China. All data collected was for the five-year period from 11/16/2018 – 11/17/2023.

4.3.1. Data Sources

Corn, soybean, and freight data was gathered from Thompson Reuters's Refinitiv Eikon. Agricensus was used for Ukraine corn basis values. DTN ProphetX was used for corn and soybean futures data. For the PNW, BRZ, and ARG, data from Thompson Reuters was the FOB cash value. All data was converted to CNF prices accordingly. Additionally, BRZ and ARG data values were reported in metric tons, so a conversion was used to report all basis values in dollars per bushel ($/bu.) Freight values were reported by Thompson Reuters in U.S. dollars per ton ($/metric ton). Conversions between metric tonnes and bushels are used in order to add FOB values and freight values to arrive at a cost-and-freight value (CNF).

4.3.2. Data Behavior

The data can be analyzed by first looking at data values charted over time. These charts provide a quick way to analyze absolute difference between origins, seasonality, correlation, trends, etc. In Figures 4.1 and 4.2, FOB Basis values for the origins included in the dataset are charted over the five-year period. These charts show how different origin values change over time. The soybean basis values seen in Figure 4.2 show increased volatility starting sometime in 2020. The same is also seen in Figure 4.1 in the corn data. This observation and previous knowledge of the industry and the price data suggests a structural break.

Figure 4.1. Corn FOB Basis

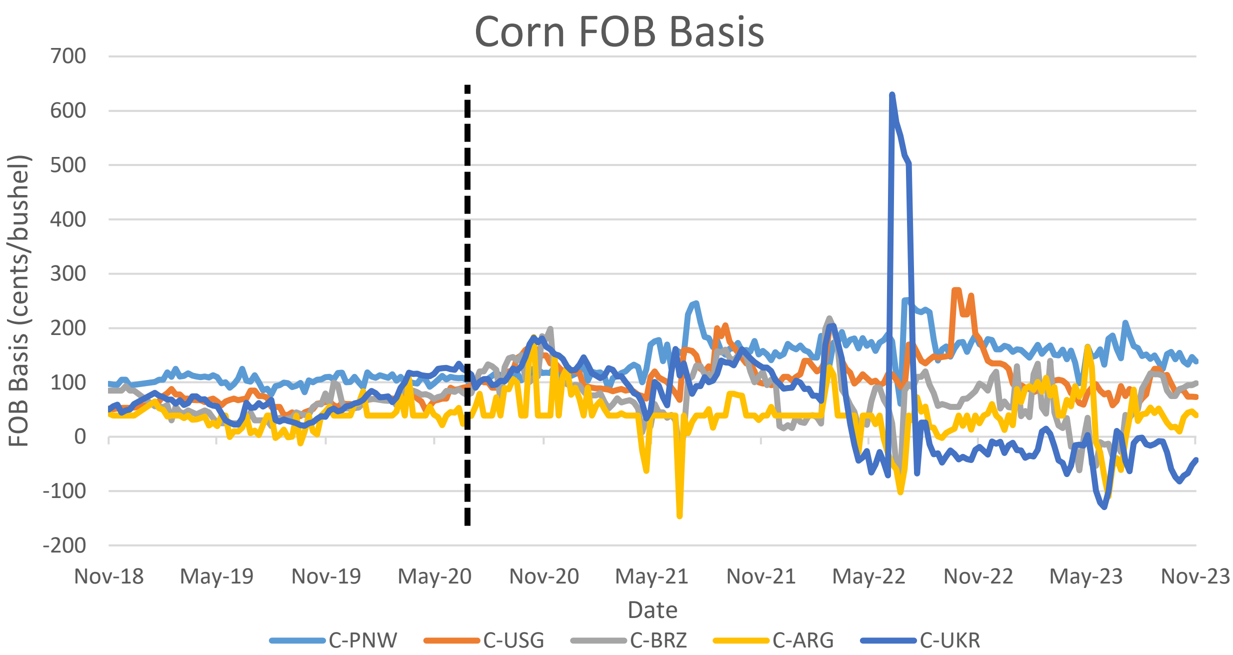
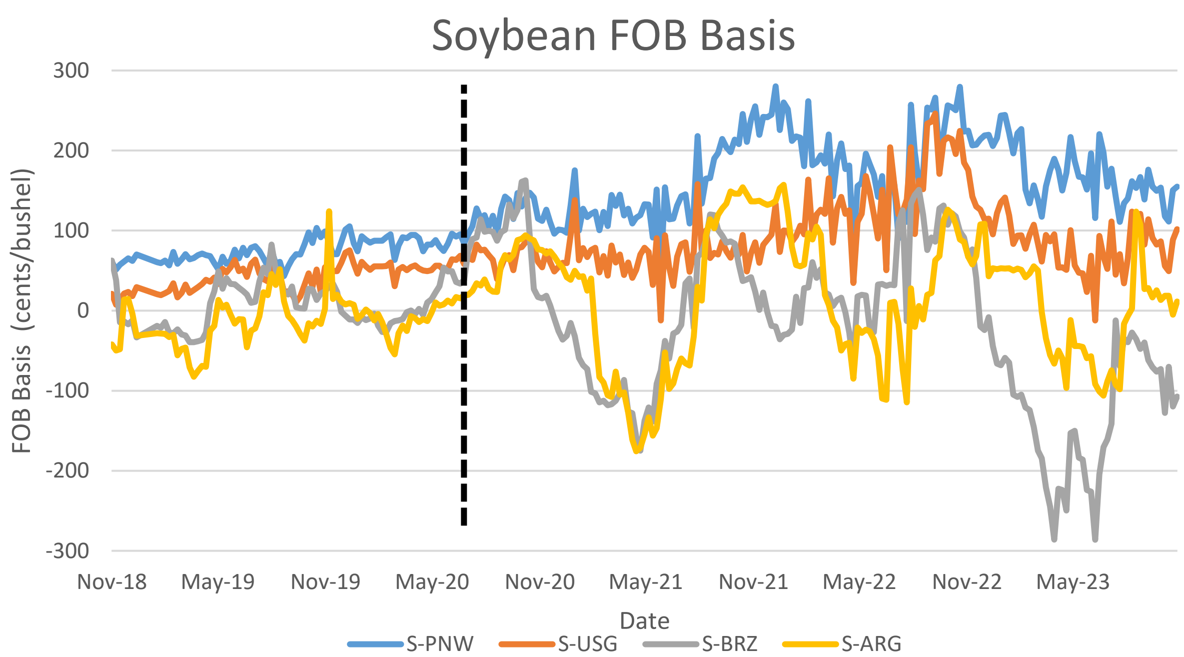
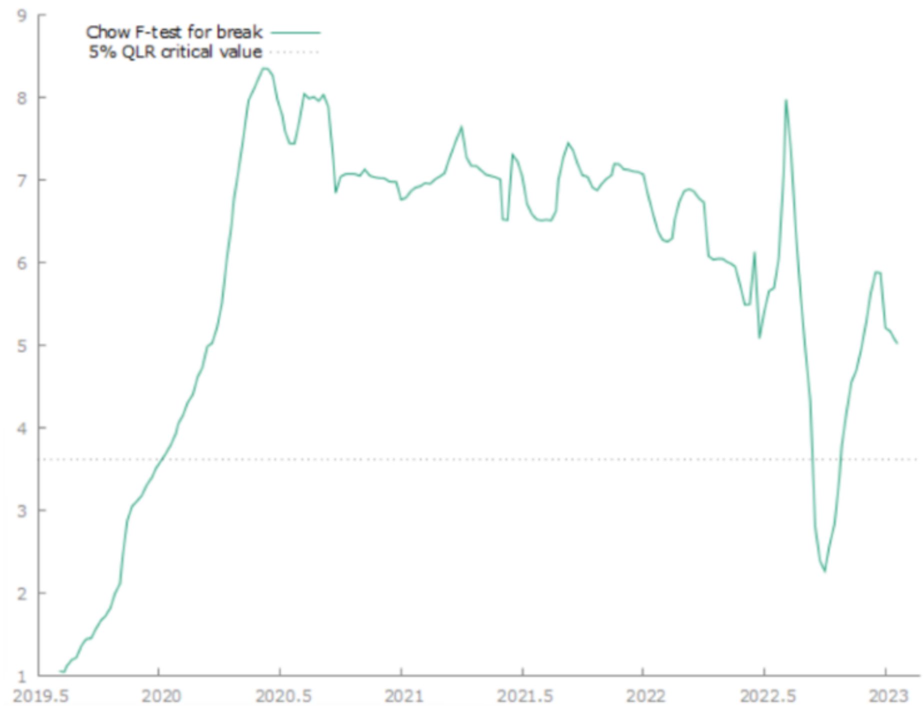


Figure 4.2. Soybean FOB Basis



To test for the date of the structural break, the Quandt Likelihood Ratio (QLR) test is performed. This test performs a Chow test at each possible date of structural break, compares the results, and returns the most likely date of the structural break. The Chow test examines the data based on the null hypothesis that there is no structural break. The idea is that if there is stationarity in the data, the out-of-sample forecasts are unbiased. The result of the QLR test using the corn data is seen in Figure 4.3. According to the QLR test, the most likely date of structural break was on June 5, 2020, with the maximum F-value of 8.35 on this date. This is consistent with the findings of Bullock et al. (2023).

Figure 4.3. QLR Test using Corn Data



To verify the results of the QLR test, a two-sample t-test is completed. These results confirmed that there is a structural change in the mean and the variance of the two samples, the first one from November 17, 2018 to June 5, 2020 and the second from June 12, 2020 to November 16, 2023. These statistical test results are summarized in Table 4.3. The F-test examines the variances of the two samples, with the null hypothesis that the ratio of variances from the two samples is equal to 1. For both corn and soybeans, we reject this null hypothesis. The 95% confidence interval of the true ratio of variances for corn is [0.064, 0.137] and for soybeans is [0.078, 0.167]. The t-test examines if the sample means are the same, with the null hypothesis that the difference between the means are equal to 0. Again, this null hypothesis is rejected in both the corn and soybean cases. The 95% confidence interval of the true difference in the means for corn is [-1.048, -0.868] and for soybeans is [-1.075, -0.873].

Table 4.3. Two-Sample T-Test Results

Commodity	**Corn**		**Soybeans**	
Value	Observed Value	P-Value	Observed Value	P-Value
Fisher's F-test	0.093	<0.0001	0.113	<0.0001
T-test	-0.958	<0.0001	-0.974	<0.0001

Due to the existence of the structural break, the data is separated into two datasets: one from 11/16/2018-6/05/2020 and the second from 6/12/2020-11/17/2023. For simplicity, these periods are referred to as pre 2020 and the post-2020, respectively. Both datasets are inputted into the model separately, and the results help illustrate the factors driving the value of the contracting provisions outputted by the empirical model. Since the dataset is split into two, it is interesting to analyze how different statistical measures changed from the pre-2020 to the post-2020 data series. The summary statistics are included in Tables 4.4 and 4.5. Green shading indicates an increase in the respective statistical measure while red shading indicates a decrease.

The summary statistics show many interesting changes between the two series of data. Perhaps the most interesting change to this study is the large increase in variance in the post-2020 data series. Across all origin variables for both corn and soybeans, a large increase is noted. This increased volatility is expected to have a large impact on the value of both the embedded origin switching option and the contract washout.

Additionally, there are large increases in the mean basis at each of these geographical origins in the more recent period. This increase is largest for U.S. ports, while the smallest increase occurs at the Ukraine port. Overall, the differences here illustrate a more volatile recent period.

Table 4.4. Pre-2020 Summary Statistics: CNF Basis (FOB Plus Ocean Shipping)

	Corn					Soybeans			
Statistic	**PNW**	**USG**	**BRZ**	**ARG**	**UKR**	**PNW**	**USG**	**BRZ**	**ARG**
# of observations	78	78	78	78	78	78	78	78	78
Minimum	1.290	1.136	1.211	0.871	1.120	1.084	1.056	0.540	0.229
Maximum	1.868	2.114	2.014	1.758	2.012	1.667	1.969	2.218	2.160
1st Quartile	1.502	1.464	1.413	1.177	1.483	1.228	1.270	0.734	0.595
Median	1.584	1.560	1.492	1.294	1.600	1.300	1.407	0.991	0.826
3rd Quartile	1.654	1.652	1.615	1.418	1.737	1.396	1.528	1.420	1.114
Mean	1.577	1.571	1.537	1.291	1.607	1.320	1.412	1.107	0.884
Variance (n-1)	0.013	0.029	0.034	0.031	0.041	0.019	0.042	0.173	0.151
Standard deviation (n-1)	0.112	0.169	0.184	0.176	0.201	0.137	0.206	0.416	0.389

Table 4.5. Post-2020 Summary Statistics: CNF Basis (FOB Plus Ocean Shipping)

	Corn					Soybeans			
Statistic	**PNW**	**USG**	**BRZ**	**ARG**	**UKR**	**PNW**	**USG**	**BRZ**	**ARG**
# of observations	180	180	180	180	180	180	180	180	180
Minimum	1.399	1.626	0.536	-0.05	-0.36	1.189	0.999	-1.71	-0.01
Maximum	3.428	4.200	4.199	3.178	7.671	3.651	3.975	3.477	3.737
1st Quartile	1.874	2.074	1.877	1.499	0.898	1.912	1.877	0.572	1.170
Median	2.260	2.491	2.135	1.817	2.020	2.383	2.309	1.507	1.635
3rd Quartile	2.528	2.833	2.552	2.102	2.506	2.873	2.769	2.288	1.971
Mean	2.230	2.529	2.220	1.790	1.870	2.411	2.386	1.395	1.635
Variance (n-1)	0.197	0.308	0.443	0.248	1.555	0.340	0.375	1.286	0.752
Standard deviation (n-1)	0.444	0.555	0.666	0.498	1.247	0.583	0.612	1.134	0.867

Another statistic of great interest to this study is the correlation between basis values at different origins. Spearman-Rank correlation values from the data set are summarized in Tables 4.6, 4.7, 4.8, and 4.9.

Table 4.6. Corn Pre-2020 Correlation

	PNW	**USG**	**BRZ**	**ARG**	**UKR**
PNW	1	0.652	0.338	0.210	-0.449
USG	0.652	1	0.111	0.274	-0.315
BRZ	0.338	0.111	1	0.334	0.085
ARG	0.210	0.274	0.334	1	-0.061
UKR	-0.449	-0.315	0.085	-0.061	1

Table 4.7. Corn Post-2020 Correlation

	PNW	**USG**	**BRZ**	**ARG**	**UKR**
PNW	1	0.685	0.430	0.378	0.081
USG	0.685	1	0.605	0.429	0.425
BRZ	0.430	0.605	1	0.480	0.437
ARG	0.378	0.429	0.480	1	0.381
UKR	0.081	0.425	0.437	0.381	1

Table 4.8. Soybeans Pre-2020 Correlation

	PNW	**USG**	**BRZ**	**ARG**
PNW	1	0.645	0.286	0.350
USG	0.645	1	0.648	0.684
BRZ	0.286	0.648	1	0.791
ARG	0.350	0.684	0.791	1

Table 4.9. Soybeans Post-2020 Correlation

	PNW	**USG**	**BRZ**	**ARG**
PNW	1	0.759	0.342	0.594
USG	0.759	1	0.570	0.483
BRZ	0.342	0.570	1	0.592
ARG	0.594	0.483	0.592	1

These correlation statistics tell an interesting story about the behavior of basis values at different geographical origins around the world. As is seen in both corn and soybeans, the highest level of correlation exists between the two major ports in the United States: the U.S. Gulf and the Pacific Northwest. Other notable observations are negative correlations of Ukraine with other origins in the pre-2020 period and the increase in correlation between origins in the corn data from the pre-2020 to the post-2020 period. The soybean data did not see this general increase. The PNW became more correlated with other origins, but the rest of the origins became less correlated. These changes impact the value of the contracting provisions in the model.

4.3.3. Data Distributions

As discussed in previous sections, this thesis utilizes a recombining binomial lattice to value the real options embedded within the contracting practices studied. This valuation method dictates certain data manipulations for proper valuation. The U.S. Gulf is specified as the state variable. Thus, it is model with the projection lattice, which is driven by a Geometric Brownian Motion (GBM) process. The GBM process drives growth from the most recently observed value based on fixed up and down moves, which are calculated using historical price volatility. This is the average of logged difference values over the data series time period. Because GBM would not return negative values, it does not work to model basis values. Thus, the projection lattices model U.S. Gulf cash prices.

To model the value of switching between origins, the prices at other geographical origins are projected using distributions specified in Palisade's @Risk software. Because these values are considered relative to the U.S. Gulf, prices are first converted to spreads. This is accomplished by subtracting the value of other origins from U.S. Gulf value at each time period. Using spreads also helps to capture and model some of the correlation between these origins. A positive spread value is interpreted as positive switching value, while a negative spread means that origin is more expensive than the U.S. Gulf and thus has negative switching value for the Chinese buyer.

After calculating spreads, Palisade's @Risk software is used to analyze the data and fit distributions. The Time Series Batch Fit was used to assign distributions to represent the historical data in order to make future projections. The distributions were chosen based on the Akaike Information Criterion (AIC). These distributions also include a correlation matrix in order to allow simulations to vary the data together according to the correct degree of correlation observed in the historical dataset. The best fit distributions are shown the Tables 4.10, 4.11, 4.12, and 4.13. Descriptions of each of these @Risk Distributions is included in Table 4.14.

Table 4.10. Corn Best Fit Distributions Pre-2020

Variable	Best Fit Distribution
USG-PNW	RiskAR1(-0.0060883,0.097617,0.62416,-0.028299)
USG-BRZ	RiskBMMRJD(0.026535,0.073471,0.070694,0.088676,0.033348,0.29518,-0.15334)
USG-ARG	RiskARMA11(0.27334,0.17587,0.86647,-0.6186,0.31965,-0.0012223)
USG-UKR	RiskAR1(-0.11909,0.11017,0.93295,-0.58603)

Table 4.11. Corn Best Fit Distributions Post-2020

Variable	Best Fit Distribution
USG-PNW	RiskBMMRJD(0.29276,0.22028,0.23708,0.038359,0.16754,0.97885,-0.071317)
USG-BRZ	RiskBMMRJD(0.32364,0.3249,0.24484,0.038359,-0.058976,1.0314,-0.4705)
USG-ARG	RiskBMMRJD(0.57535,0.34304,0.25828,0.030413,1.3867,3.4434E-07,0.33523)
USG-UKR	RiskBMMRJD(0.88131,0.26966,0.074224,0.029365,-0.13641,5.3233,1.2947)

Table 4.12. Soybean Best Fit Distributions Pre-2020

Variable	Best Fit Distribution
USG-PNW	RiskBMMR(0.094066,0.075076,0.13181,0.11271)
USG-BRZ	RiskBMMRJD(0.35612,0.1863,0.22449,4.1666E-17,0.46042,0.17891,0.24463)
USG-ARG	RiskBMMRJD(0.62842,0.15408,0.26597,0.088676,0.19839,1.143,0.51361)

Table 4.13. Soybean Best Fit Distributions Post-2020

Variable	Best Fit Distribution
USG-PNW	RiskBMMRJD(0.53026,0.12353,0.0051981,0.054866,0.063718,0.51468,0.092692)
USG-BRZ	RiskARMA11(0.97042,0.43063,0.95594,-0.38859,1.8618,0.30654)
USG-ARG	RiskARMA11(0.73895,0.36038,0.93538,-0.25581,0.90649,0.11482)

Table 4.14. @Risk Distribution Descriptions

@Risk Distribution	Description
AR1(mean, standard deviation, auto-regressive parameter, value at time=0)	A stationary stochastic process where one lagged value is used to predict the next value of a series.
ARMA11(mean, standard deviation, auto-regressive parameter, moving average parameter, value at time=0, noise at t=0)	A stationary stochastic process where one lagged value and one lagged error are used to predict the next value in a series.
BMMR(mean, standard deviation, rate of reversion to mean, value at time=0)	A continuous-time stochastic process where values of the series revert to a long-term equilibrium.
BMMRJD(mean, standard deviation, rate of mean reversion, Poisson parameter for frequency of jumps, mean of jump, standard deviation of jump, value at time=0)	A continuous-time stochastic process where values of the series revert to a long-term equilibrium, and jumps or random shocks occur.

Source: (Palisade n.d.)

4.4. Summary

This chapter details the design of the empirical model used to value the contracting practices that are of interest to this study: contract washouts and embedded origin switching options. This includes a thorough discussion of the data, including its sources, behavior, and distributions. The model uses price data from several origins. They are CNF prices of grain delivered from their respective ports to Dalian, China. The models switched to price data instead of basis data because of the constructs of the recombining binomial lattice. Additionally, spreads are used relative to U.S. Gulf prices in the models. A base case representing the most likely situation relevant to the industry is described, which is used in contrast to several sensitivity analyses designed to illustrate how the most relevant factors drive changes in the value of washouts and origin switching. The results of the model are presented in the following chapter.

5. RESULTS

5.1. Introduction

This thesis investigates washouts and embedded origin switching options. Previous chapters have documented the elevated occurrence of these contract practices in the grain trading industry. However, the values of these practices in the trade are seldom reported. To illustrate the value of these options, illustrative examples are constructed that represent scenarios likely to occur in industry practice. These operate under the assumption that traders are hedged and thus the variables affecting the values are the changes in prices relative to the U.S. Gulf. Models are built to value both embedded origin switching options and contract washouts, as defined previously. The results of these models are reported and discussed in this chapter. The scenarios the models represent, with their assumptions, are meant to serve as a proposed example for the grain industry to adopt as it adapts to the increasing frequency of contract washouts and the demand for embedded origin switching options in grain contracts.

This chapter begins with a presentation of the base cases, which are meant to be illustrative examples of these industry practices. These base case models are built using price data for both corn and soybeans. The results of the models built with these specifications are analyzed in depth. In addition, sensitivity analysis is conducted on these models to illustrate how important factors change the value of contract washouts and embedded origin switching options. Specifically, volatility, correlation, time, and the number of optional origins are analyzed as variables of interest. The overall results of these models are interpreted and summarized at the conclusion of this chapter.

5.2. Base Case Definition

5.2.1. Trading Strategies

A base case scenario is defined to illustrate a likely situation in which embedded origin switching options and contract washouts are used. These terms are defined in earlier chapters. The embedded switching option is a term that is negotiated (and thus embedded) into the original contract between the buyer and seller. This term gives the buyer the option to switch the geographical origin from which the contract would be physically settled. This option exists for a specified amount of time and allows the buyer to switch from their contracted price at one origin to the prevailing market price at another origin. The seller receives a premium for providing this option.

The contract washout is a related contracting practice, with some important distinctions. A contract washout is defined as a contracting practice that occurs after the original contract is created, or ex-post. It involves a buyer first cancelling their original contract and then switching origins. This switch could be negotiated with the same seller who is able to fulfill the buyer's grain needs at a different origin, or the buyer could find a completely different seller to re-contract with. Because this practice is not embedded in the original contract, there is no premium associated with it, but rather there is a cost of cancelling the original contract. This cost is negotiated between the buyer and seller as the buyer attempts to financially settle their contractual obligations, as opposed to physical settlement. It is assumed that the buyer pays the difference between their contracted price and the current prevailing price at the origin which was specified in the original contract.

It is important to remember that while this study defines a contract washout as a cancellation and subsequent origin switch, some in the industry trade use the term washout as synonymous with a cancellation. They refer to a simple cancellation as a washout without mention of replacing their contracted grain with grain from an alternative origin. However, for the purposes of the models in this thesis and the interpretations of their results, washouts involve both a contract cancellation and subsequent origin switch.

The definitions of these contract practices drive the models, as well as the scenarios presented in the base cases. Additionally, the base cases serve as a benchmark in the sensitivity analyses. Because both contracting practices are becoming more common, the base case is defined similar to the many documented cases of embedded origin switching options and contract washouts. However, because of the differences between contract washout and embedded origin switching options, two base cases are defined. Base cases are the same for corn and soybean results, except the soybean base case does not include a Ukraine origin. These base case definitions are discussed more thoroughly in the previous chapter but are summarized here as well in order for convenience.

5.2.2. Definitions and Assumptions

The base case for the embedded origin switching option is a Chinese grain importer who has negotiated a contract with a multi-national commodity trading firm. During negotiations, the Chinese buyer and the multi-national seller agreed to include a clause embedded in the contract that allows for the origin of the grain to be switched at the option of the Chinese buyer. The contract plans for the grain to be shipped from the U.S. Gulf but allows for the Chinese buyer to switch the origin of the grain to the PNW, Brazil, or Argentina (Ukraine is also included as an optional origin in the corn model). This embedded origin switching option provides value to the buyer, and this must be shared with the seller in the contract terms or as a premium payment.

This premium is a negotiable term and analysis of how this value is shared is included at the end of this chapter.

The base case used to illustrate a contract washout is similar, with some distinctions. Once again, a Chinese grain importer contracts with a seller. Their contract is to be fulfilled with the physical delivery of grain from the U.S. Gulf. There are no provisions included in the contract for origin switching. Thus, if the Chinese firm wishes to participate in international spatial arbitrage opportunities, they must cancel their contract. To do this, they negotiate financial settlement of their original contract, rather than taking physical delivery to settle contractual obligations. Once the Chinese firm cancels their contract, they can execute the second half of the washout by switching to another origin and buying their grain from any firm. This illustrates both parts of the contract washout: cancellation and origin switch.

As discussed in sections in the previous chapter focused on the data, these models are run using two separate time series of data. The first series is from 11/16/2018-6/05/2020 and the second includes 6/12/2020-11/17/2023. This is due to a structural break in the data, which is represented by differing data distributions. The first period is referred to as pre-2020 and the second is called post-2020. The separation of these periods serves to illustrate how the value of the embedded switching option and contract washouts change given changes in price data behavior. Additionally, the models are run separately using corn and soybean price data.

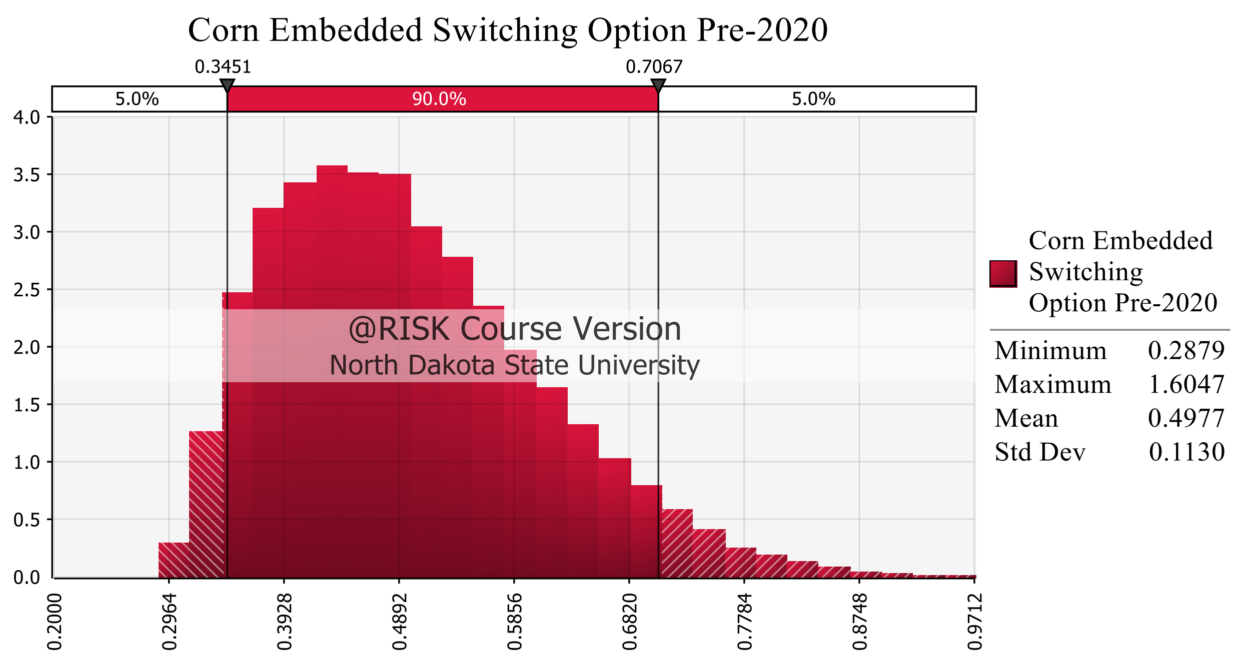
5.3. Base Case Option Values

5.3.1. Embedded Origin Switching Option

There are four base case results for the embedded origin switching options: corn pre- and post-2020 and soybean pre- and post-2020. The corn and soybean models are identical except for one distinction: the corn model includes a Ukrainian origin. Differences between the pre-2020 and post-2020 periods are due to the increased volatility and changes in correlation in the later period, which are represented in the Monte Carlo distributions driving the model outputs.

The embedded origin switching option using corn data from the pre-2020 period is valued at $0.50/bu., as seen in the probability density function in Figure 5.1. The Chinese grain buying firm would have to share this value in terms of a premium with the seller who is providing the optionality. This premium may be negotiated as such or may be added into the cash price specified in the contract to be paid by the buyer to the seller. The empirical result of the model is a mean value. As buyers and sellers negotiate the amount of a premium, they must consider the probability that each of them would profit from the transaction.

Figure 5.1. Corn Embedded Origin Switching Option Value Pre-2020



In order to evaluate these probabilities, the value can be shown as cumulative density function, as in Figures 5.2 and 5.3. If the buyer were to pay the average value of $0.50, they would have a 44% chance of achieving a net profit on the transaction. However, the value of switching is expected to be lower than the premium paid 56% of the time. If the premium was

75% of the average value of the embedded option, it would be $0.37. In this case, the buyer is expected to profit from having a switching value that is higher than the premium paid at a frequency of 88% of the time. The buyer is expected to have a loss only 12% of the time. The exact way the buyer and seller arrive at a premium is explored in a later section of this chapter.

Figure 5.2. Corn Embedded Origin Switching Option Premium 100%

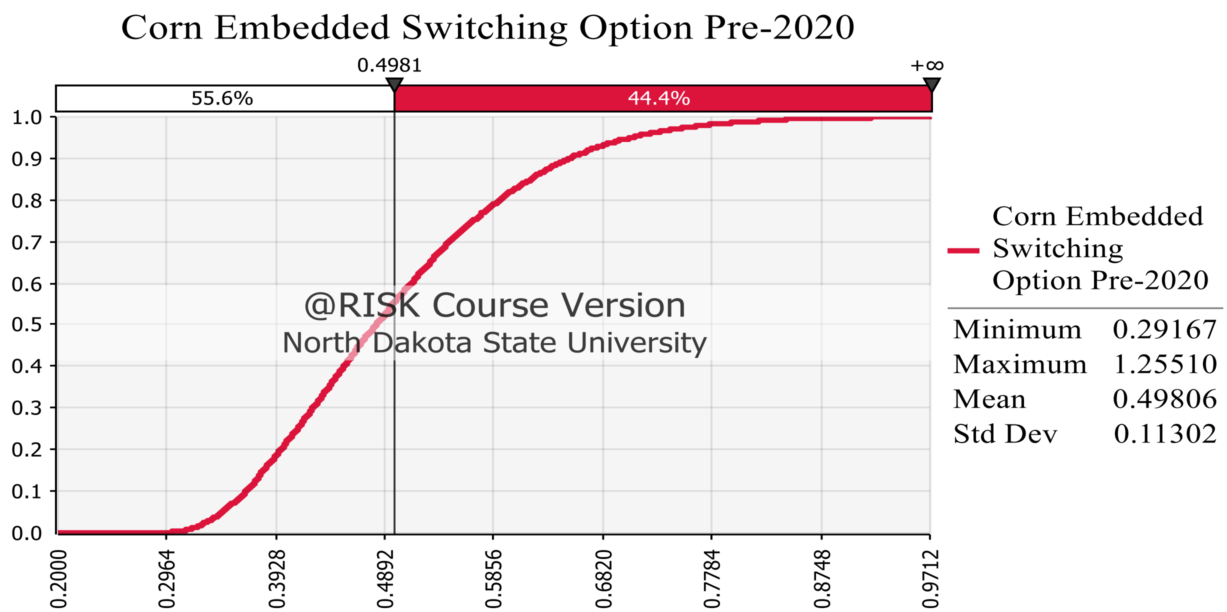
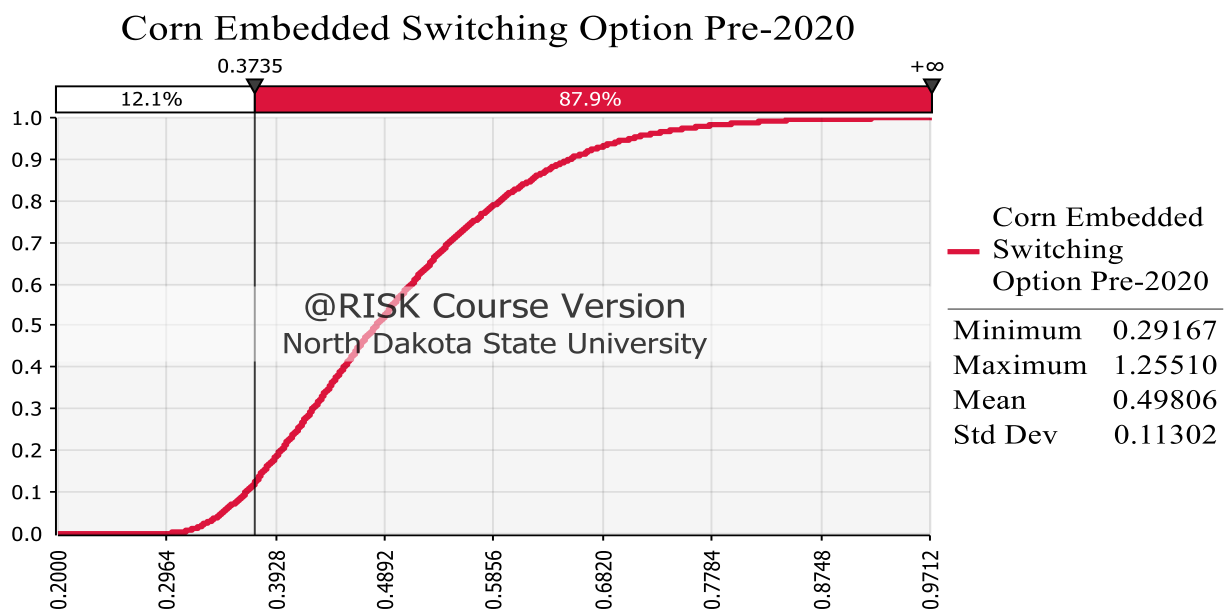
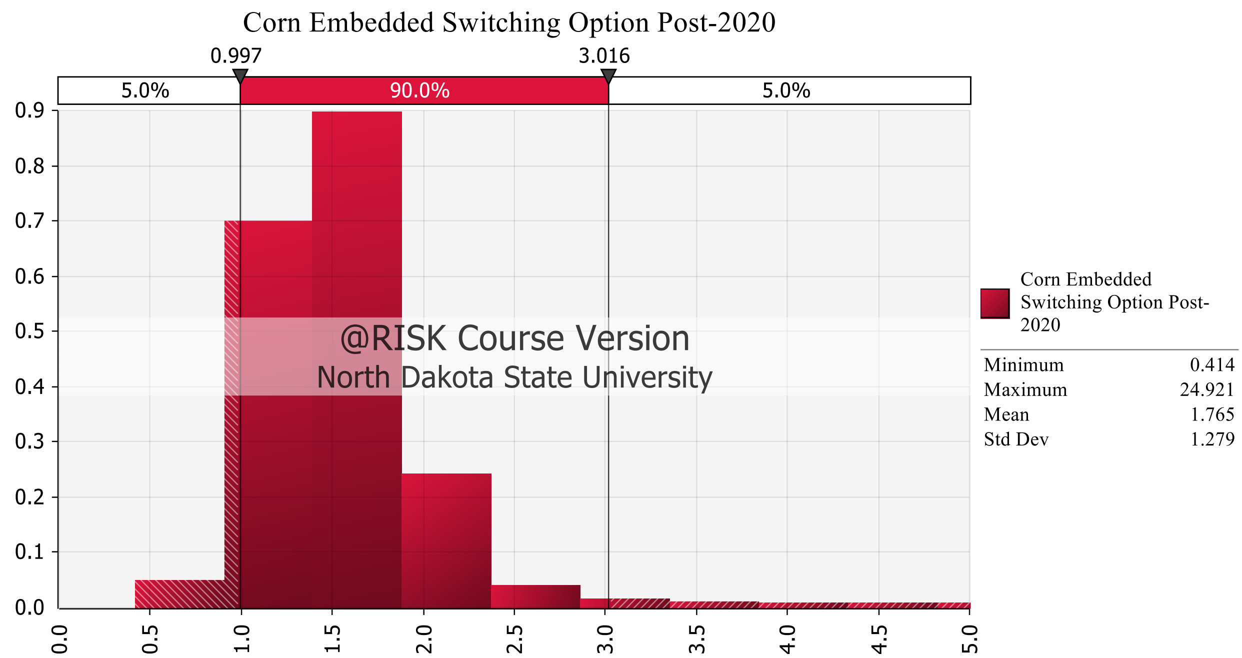


Figure 5.3. Corn Embedded Origin Switching Option Premium 75%



The embedded origin switching option becomes much more valuable in the post-2020 period. The value of the embedded option is $1.77/bu., as seen in Figure 5.4. This is substantially greater than in the pre-2020 case. The most likely reason for this is the increased volatility in the post-2020 prices. Again, this value would be shared between the buyer and the seller per their negotiations. However, in the unlikely case that the seller provides the optionality at no cost, this embedded contract provision is expected to provide $1.77/bushel in savings to the grain buyer.

Figure 5.4. Corn Embedded Origin Switching Option Value Post-2020



The embedded origin switching option has similar values in the base case using the soybean data. In the pre-2020 period, the value of the switching option embedded in a grain contract is $0.90, as shown in Figure 5.5 as the mean of 100,000 iterations in the Monte Carlo simulation. As expected, this value becomes much higher in the post-2020 period. This is due to the price data behavior, including higher volatility post-2020. Figure 5.6 reports a value of the embedded origin switching option as $2.03. This value is most often shared between the buyer and seller per a negotiated sharing parameter.

Figure 5.5. Soybean Embedded Origin Switching Option Pre-2020

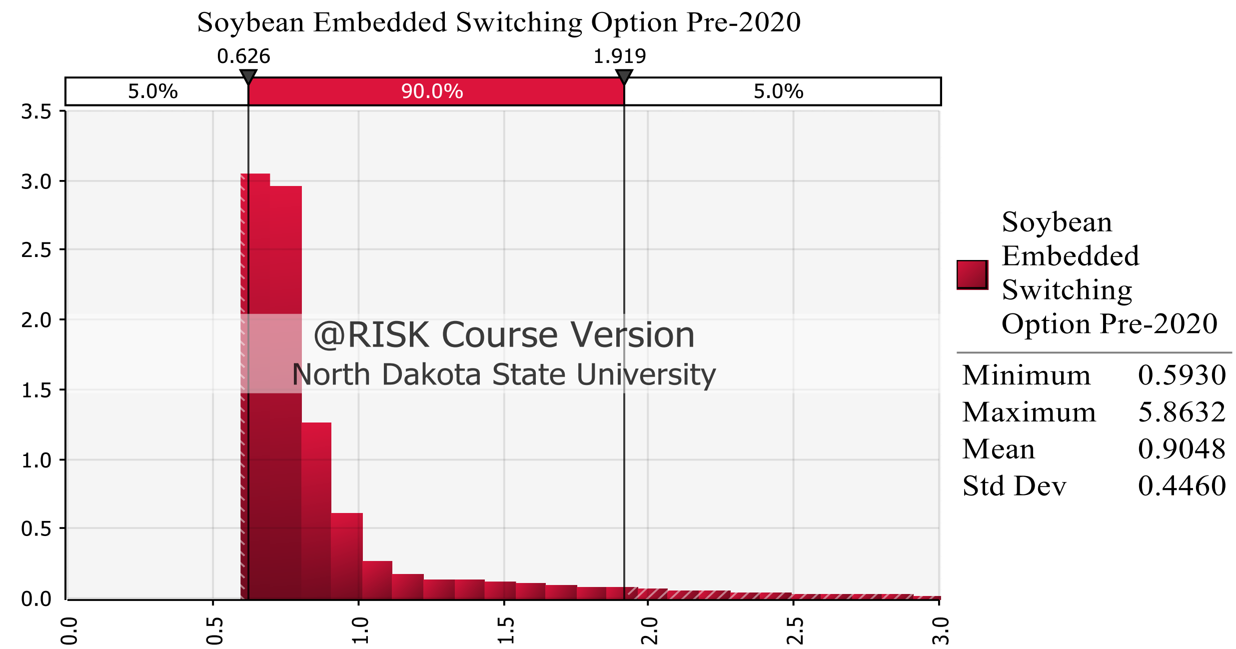
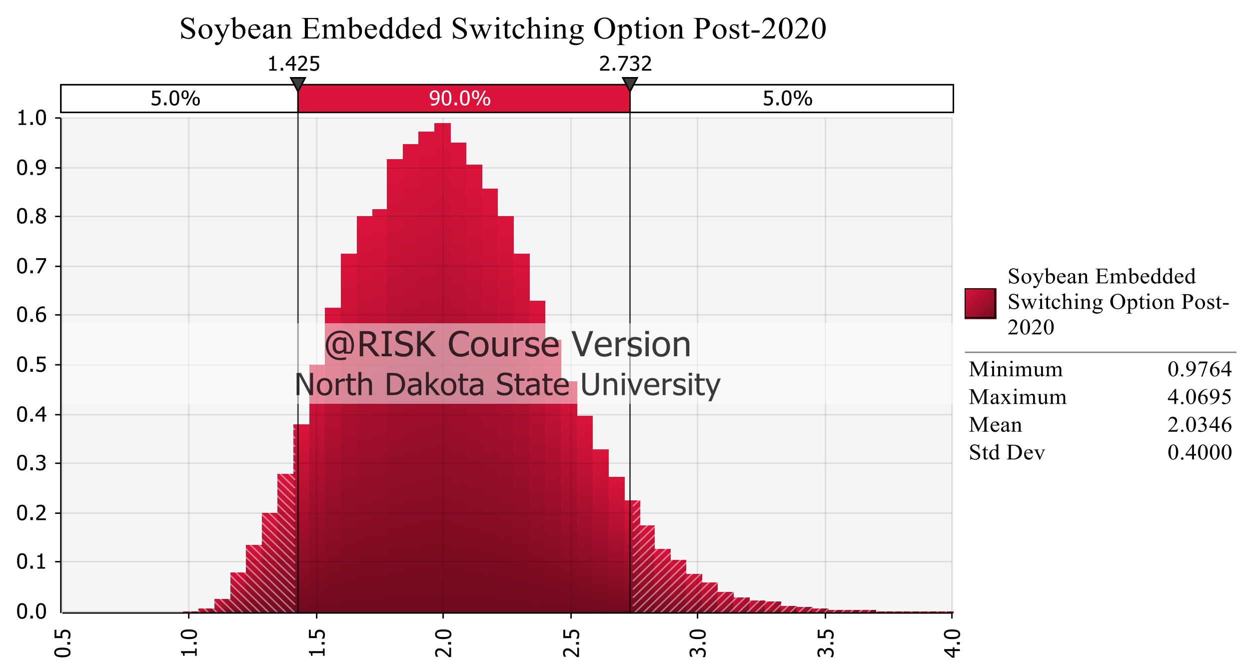


Figure 5.6. Soybean Embedded Origin Switching Option Post-2020



5.3.2. Contract Washouts

There are four base case models for contract washouts: corn pre- and post-2020 and soybeans pre- and post-2020. In these models, the buyer must cancel their contract if they wish to switch to another origin. The cost of canceling their contract is assumed to be the difference between their contracted price and the current price at the U.S. Gulf. This cost affects the value of the contract washout. This is a compound option, including first the option to abandon the original contract and second the option to switch origins.

The corn contract washout is valued at $0.46 using the pre-2020 price data distributions. This is $0.04 less valuable than the embedded origin switching contract calculated using the same data. This difference is attributed to the cost of cancelling the original contract in order to execute the contract washout. This same relationship is observed in the model results using the post-2020 data. The corn contract washout is valued at $1.68, which is $0.07 less than the corn embedded origin switching option post-2020. The values from the Monte Carlo simulations for the corn contract washouts are displayed in Figures 5.7 and 5.8.

Figure 5.7. Corn Contract Washout Pre-2020

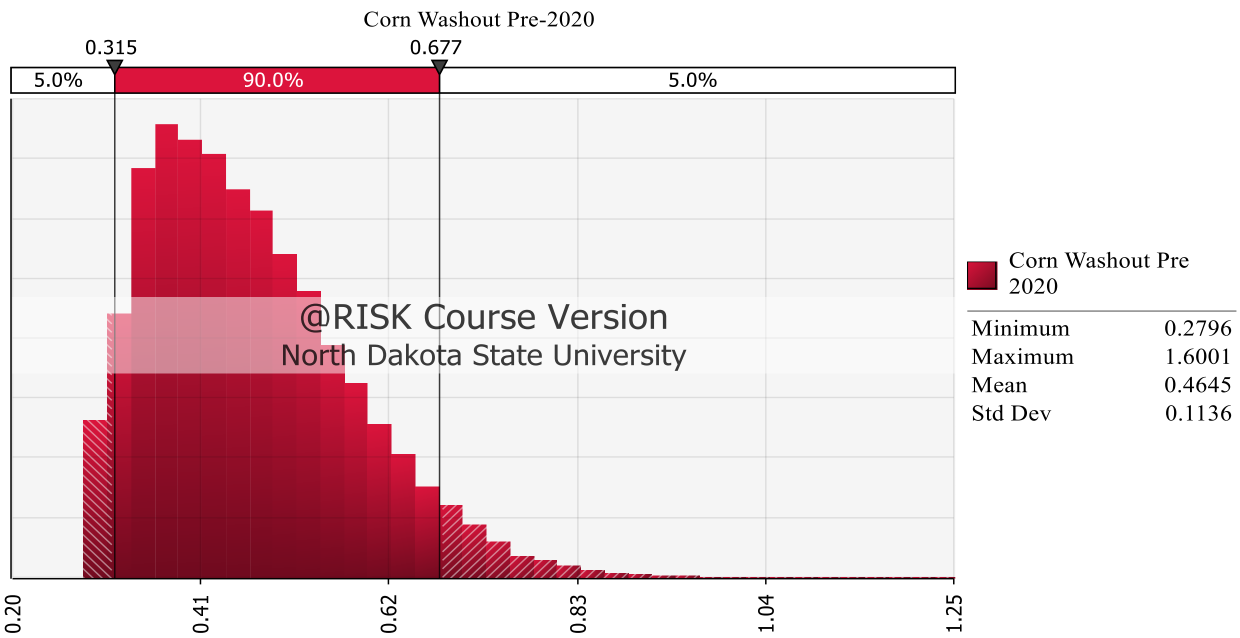
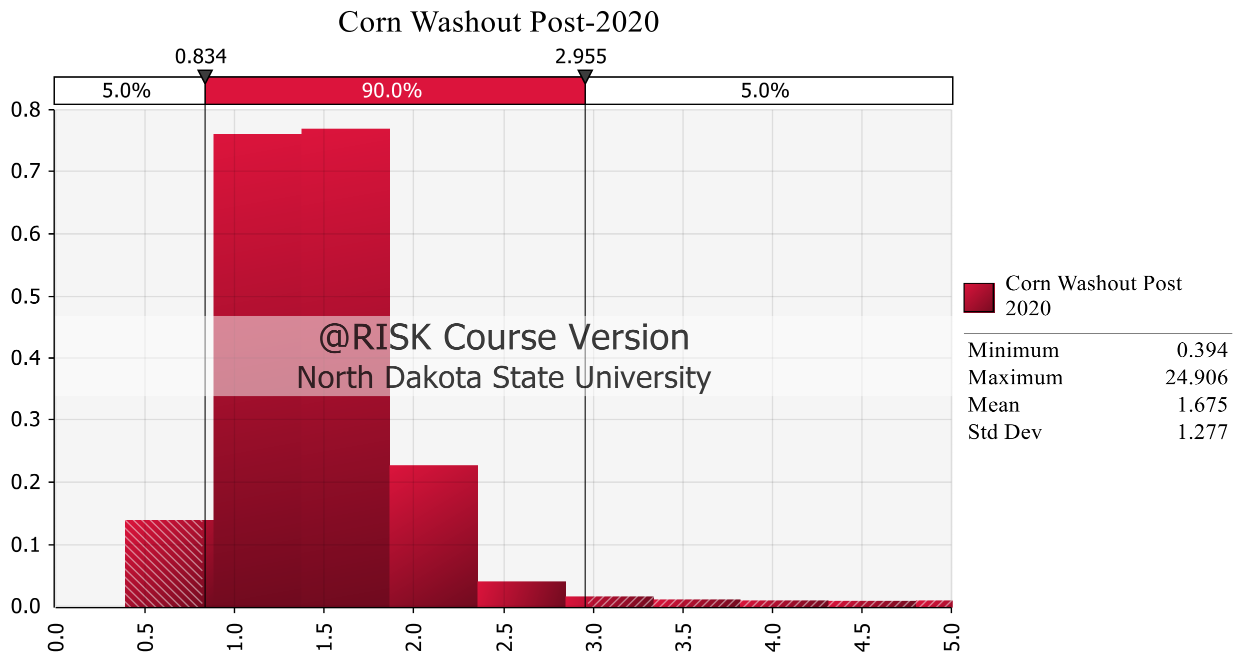


Figure 5.8. Corn Contract Washout Post-2020



The soybean contact washout is valued at $0.88 in the pre-2020 period. This means that the ability to washout of contracts is worth $0.88/bushel for the Chinese grain buyer. Once again, the washout has less value than the embedded switching option: the washout is $0.02 less valuable. The post-2020 period contract washout is much more valuable than in the pre-2020 period. The soybean contract washout model returned a mean value of the washout over 100,000 iterations of $1.93. This is $0.10 lower than the embedded switching option for soybeans in the post-2020 period. The values of the soybean contract washouts are shown in Figures 5.9 and 5.10.

Figure 5.9. Soybean Contract Washout Pre-2020

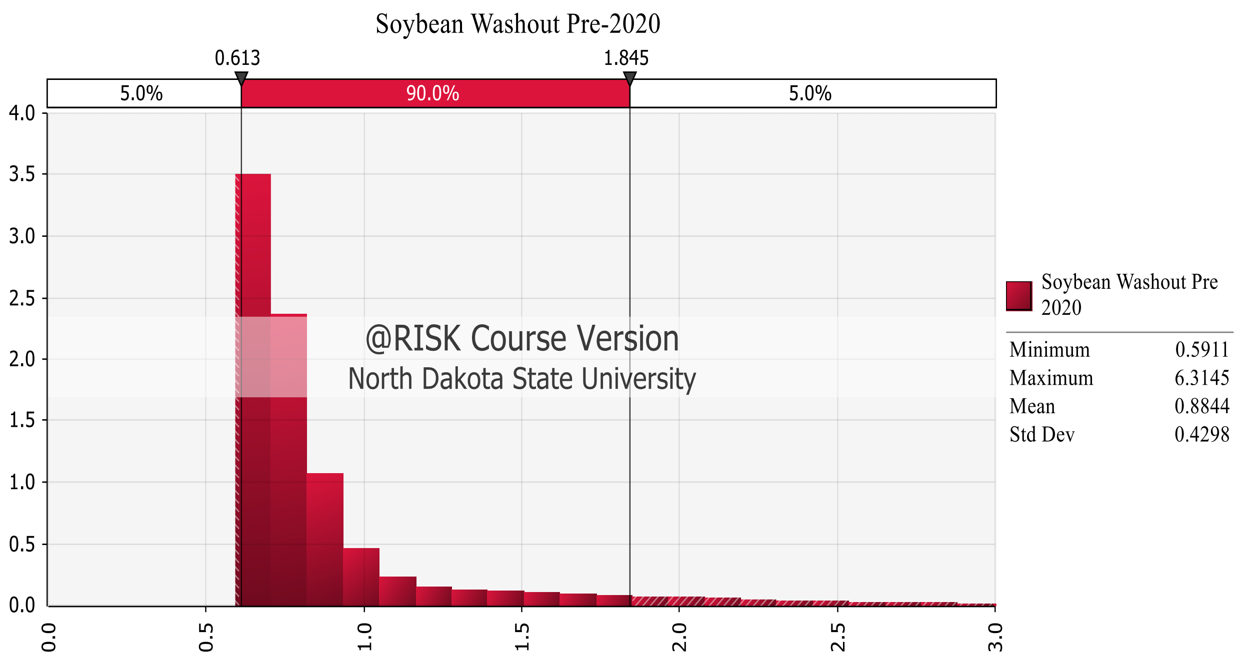
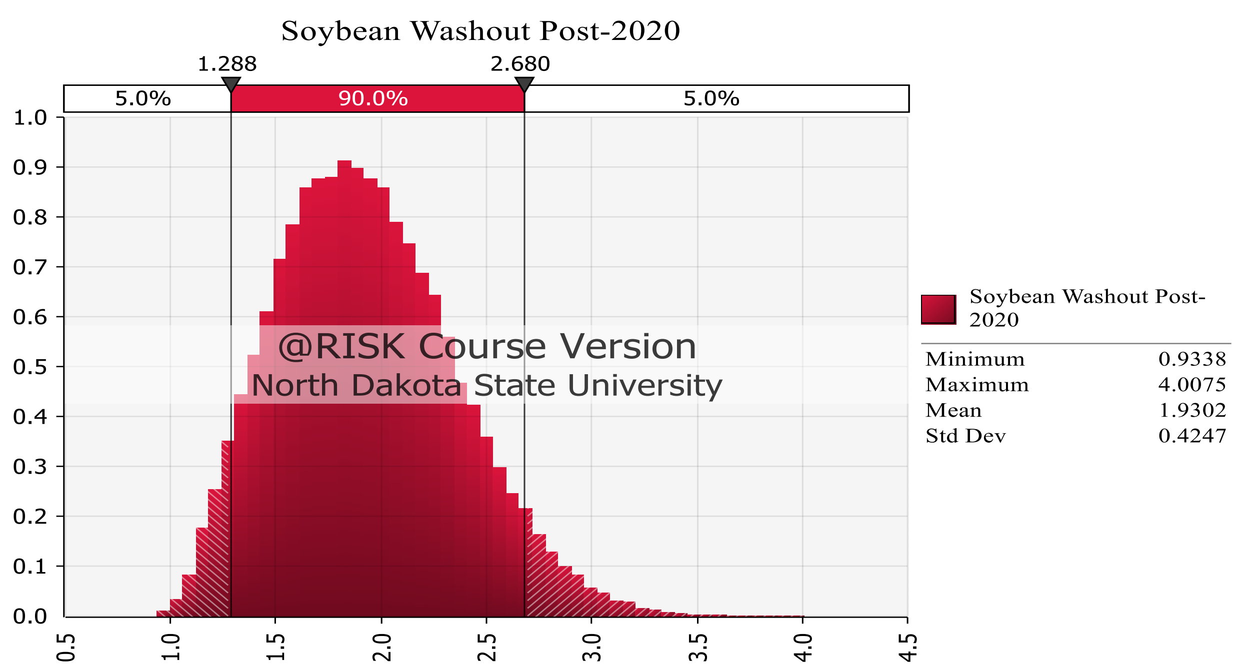


Figure 5.10. Soybean Contract Washout Post-2020



The mean values of the contract washouts show that this contract practice is valuable to grain buyers. Contract washouts are only a few cents less valuable than embedded origin switching options, and buyers don't have to pay a premium to execute them. Instead, they have to cancel their contracts. The models assume the cost of this is equal to the difference between the current price at the U.S. Gulf and the contracted price. However, this cost could be much higher or lower, depending on how the buyer and seller agree to financially settle the original contract. Not all buyers can demand contract cancellations without seriously damaging their trade relationship with the seller. Thus, these buyers would have incentives to negotiate for embedded origin switching options. Additionally, sellers have incentives to embed origin switching options into their contracts, as it allows them to keep the business of the buyer, even if it moves from one geographic origin to another. Additionally, if the option to switch origins is negotiated into the contract at the beginning, the seller can better manage grain flows through their value chain.

5.4. Sensitivity Analysis

Several variables of interest are examined further to investigate the factors affecting the value of embedded origin switching options and contract washouts. The base case results serve as a point of comparison when relevant variables are changed, with everything else held constant. Based on option theory and previous studies, volatility, correlation, and time are selected as variables to conduct sensitivity analysis with. Additionally, the number of origins available as optional origins for the grain buyer in the embedded origin switching option is varied to examine how it changes the value. The exact manner in which these sensitivity results are obtained is detailed in the following sections, and results from the sensitivity analyses are summarized in Table 5.1. Base case results are also included for comparison purposes. These are mean values to the buyer.

Table 5.1. Sensitivity Analysis Results

Model		**Corn**		**Soybean**	
Embedded Switching Option		Pre-2020	Post-2020	Pre-2020	Post-2020
Base Case (5 weeks with historical data)		$ 0.50	$ 1.77	$ 0.90	$ 2.03
Sensitivities:					
Time (Weeks)	20	1.04	2.60	2.23	3.48
Volatility (σ)	+10%	0.52	1.82	0.94	2.09
	-10%	0.47	1.75	0.87	1.98
Correlation	+10%	0.48	1.71	0.89	2.00
	-10%	0.52	1.83	0.92	2.09
# of Optional Origins	1	0.49	0.93	0.89	1.32
Contract Washout					
Base Case		$ 0.46	$ 1.67	$ 0.88	$ 1.93
Sensitivities:					
Time (Weeks)	20	1.04	2.61	2.23	3.47
Volatility (σ)	+10%	0.48	1.69	0.90	1.97
	-10%	0.45	1.67	0.87	1.89
Correlation	+10%	0.45	1.64	0.88	1.88
	-10%	0.48	1.70	0.91	1.98

5.4.1. Volatility

The volatility of price levels is a very important factor in the value of the contract practices that are the focus of this thesis. In analyzing the price data for both corn and soybeans, it is visually apparent that volatility has increased in recent years. In fact, this change is one of the reasons for the structural break that occurred in June of 2020. Thus, it is concluded that volatility is a large factor in causing the real option values to increase so significantly from the pre-2020 period to the post-2020 period.

To formally analyze how changes in the volatility affect the value of contracting practices the volatility of the prices at each origin is altered. Using Palisade’s @RiskSimTable feature, the volatility is allowed to vary from 25% to 200% of the base case volatility. In the base case, the volatility is equal to the historical calculations from the dataset. These charts are completed using the specifications from the corn embedded origin switching option pre-2020 and the soybean contract washout post-2020 models, and the results are graphed in Figures 5.11 and 5.12. These results show that as volatility increases, so does the value of both the embedded origin switching option and the ex-post contract washout.

Figure 5.11. Corn Volatility Sensitivity Analysis

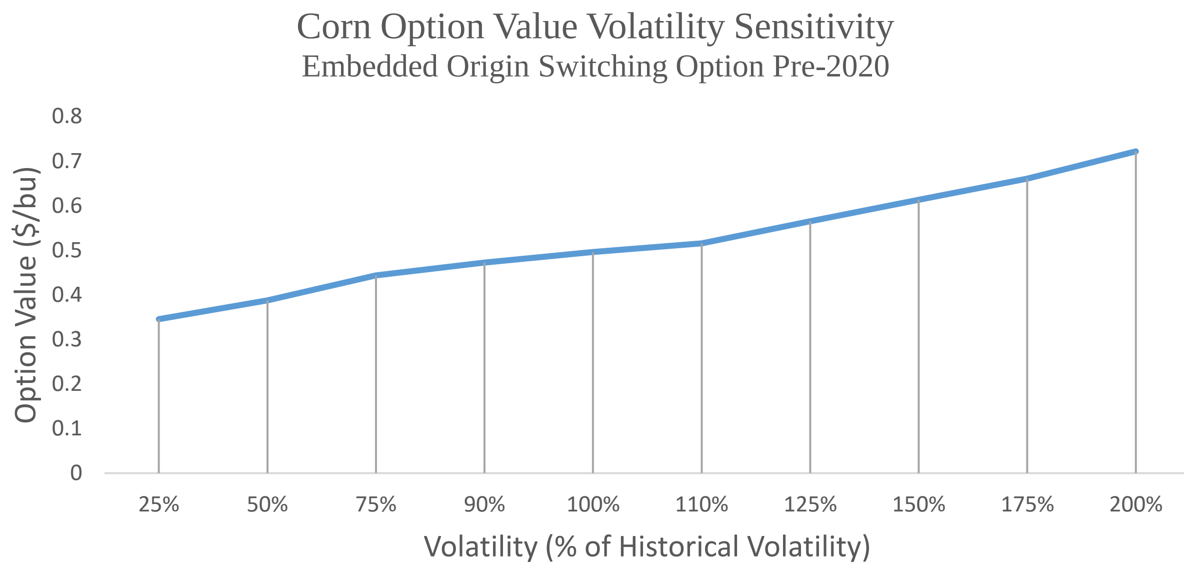
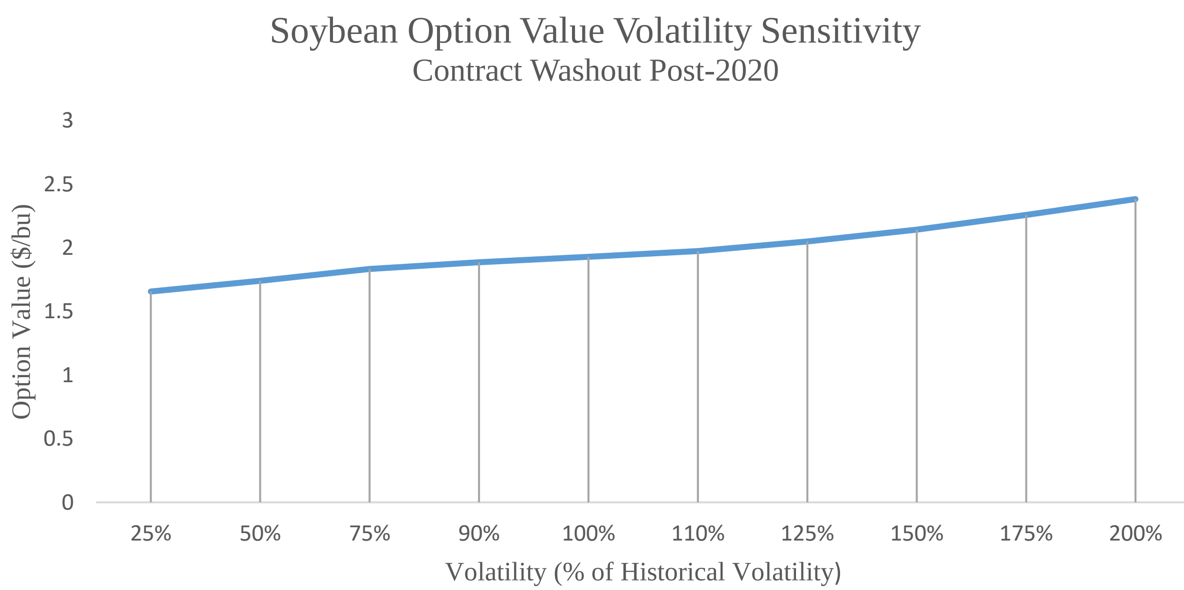


Figure 5.12. Soybean Volatility Sensitivity Analysis



Sensitivity analysis on volatility is done on each of the base case models as well. Historical volatility is varied by plus and minus ten percent (90% and 110%). The results of these sensitivity analyses are seen in Table 5.1 and their probability density function figures are included in Appendix A. These findings support the conclusion that as volatility increases, so does the mean value of these real option contracting practices.

This factor is of the utmost importance. From the pre-2020 to the post-2020 period, the standard deviation of corn basis origin prices increased an average of 298%. In other words, in the post-2020 period, the volatility is 398% of the pre-2020 period. This accounts for a large portion of the change in the values of the real option values from pre-2020 to post-2020.

5.4.2. Correlation

The correlation between the prices at different geographical origins is another important factor that affects the value of both embedded origin switching options and contract washouts. Intuitively, higher degrees of correlation are expected to decrease the value of the real options. If prices move together with a high degree of correlation, spatial arbitrage opportunities do not exist to induce origin switching. However, with lower degrees of correlation between prices at different origins there are more opportunities for spatial arbitrage profits.

To conduct sensitivity on this factor in these models, the correlation between different origins is allowed to change, while keeping all other factors constant. The model uses price spreads. To alter the correlation between the origins, the standard deviation of the price spread is increased. As the standard deviation of the spread increases, the correlation decreases. Inversely, the correlation strengthens as the standard deviation of the spread decreases. The sensitivity models increase the correlation by multiplying the standard deviation of spreads by 90% (decreasing standard deviation by 10%). Correlation is weakened by multiplying the spread’s standard deviation by 110% (increasing standard deviation by 10%). This is done for each of the eight base cases. Additionally, this is extended across a greater range (25% to 200%) for two select base case models, which illustrates the relationship that holds throughout all the models. This is done for both the embedded origin switching option using corn price data from the pre-2020 period and the contract washout using soybean price data from the post-2020 period. The results from these sensitivity analyses are shown in Figures 5.13 and 5.14. Additionally, the results of each individual sensitivity analysis are summarized in Table 5.1 and shown in Appendix A with their individual probability density functions and relevant statistics.

The correlation sensitivities all demonstrate the same relationship: as correlation increases, the option value decreases. Inversely, as the correlation between prices at different geographical origins weaken, the value of both the embedded origin switching option and the ex-post contract washout increases. These relationships are shown in Figures 5.13 and 5.14. As the standard deviation of the price spreads increase the correlation decreases, which in turn leads to an increase in the real option values. As the standard deviation increases from 25% to 200% of the base case value, the option values of the embedded switching option using corn price data from the pre-2020 period increases from $0.39 to $0.69. The ex-post contract washout value, using soybean price data from the post-2020 period, also increases as the standard deviation of the price spreads increase, ranging from $1.64 to $2.44.

Figure 5.13. Corn Correlation Sensitivity Analysis

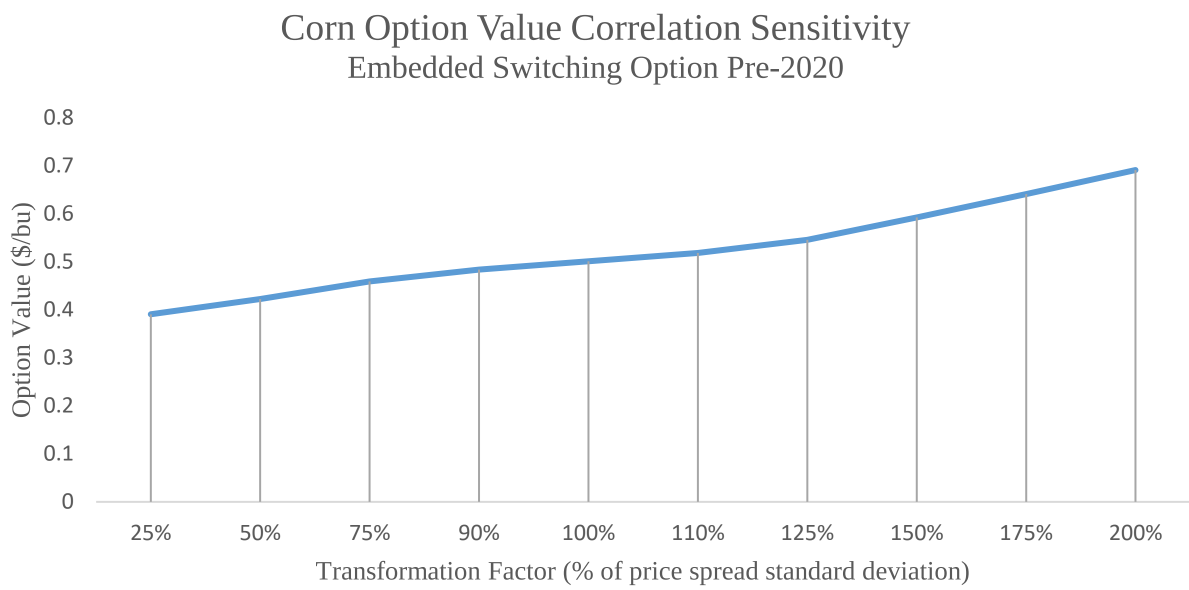
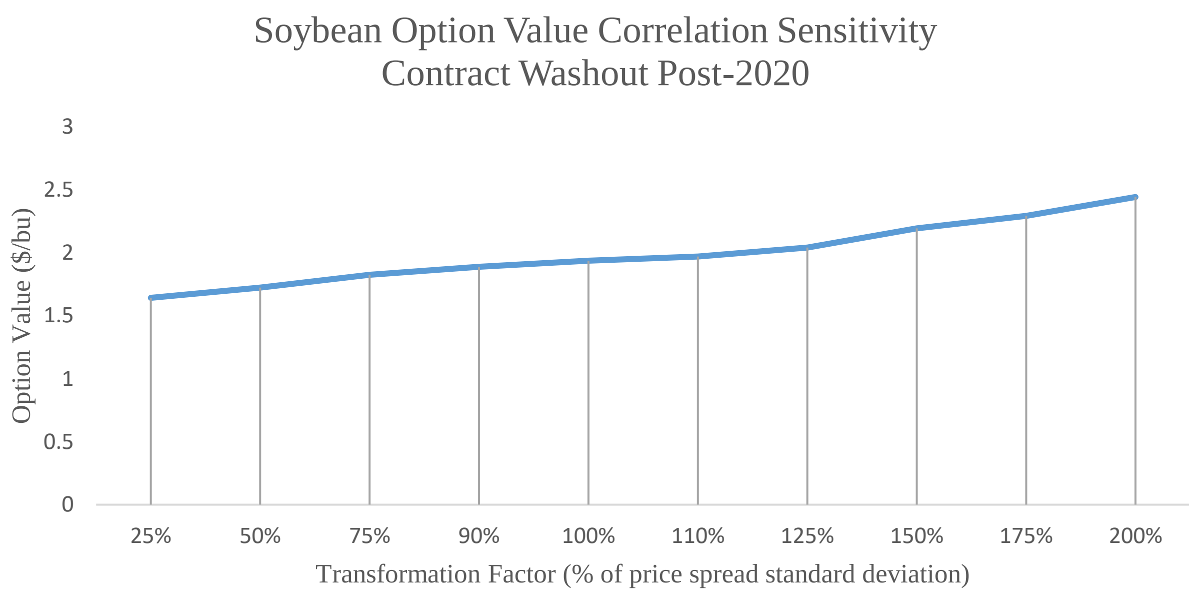


Figure 5.14. Soybean Correlation Sensitivity Analysis



This same relationship is observed when the correlation is allowed to vary by only 10% in either direction. While the values only change by $0.01-$0.03 using pre-2020 data and $0.03-$0.06 using post-2020 when compared to the base cases, stronger correlation leads to lower option value and weaker correlation is associated with higher option value. This relationship has important implications for real-world applications. In more uncorrelated markets, the value of these contracting practices escalates.

5.4.3. Time

In option pricing theory, time until expiration is an important factor. The relationship between time and the option premium is expected to be non-linear. This is also the case in real option methodology. Time and real option value are related in a non-linear way when Geometric Brownian Motion processes, like the one driving the real option valuation in these models, are used. When analyzing the mean value of embedded origin switching options and contract washouts, time is shown to be an important factor. In the base case, the ability to switch exists for 5 weeks. This value is changed to 20 weeks for the purpose of sensitivity analysis. The results of changing each of the eight base case models from 5 weeks to 20 weeks is summarized in Table 5.1 and the graphs are shown in Appendix A. Changing the length of time the optionality exists for the Chinese grain buyer has significant impact on the value of both the embedded origin switching option and the contract washout.

The value of the embedded origin switching option more than doubled in the pre-2020 period for both the corn and soybean models when the time of optionality was extended. The mean value of the real option using corn prices increased $0.54 and the value from the model using soybean prices increased $1.33. This was a 108% and 148% increase, respectively. Similar results are observed in the post-2020 period. In the model using corn price data, the real option value increased by $0.83, which is a 46% increase. The value of the embedded origin switching option increased by $1.45 in the model using soybean price data, which was a 71% increase.

The contract washout also became more valuable with a longer period of optionality. In the pre-2020 models, the mean value more than doubled. The value of the contract washout increased by $0.58 in the model using corn prices and by $1.35 in the model using soybean prices, which is a 126% and 153% increase, respectively. In the post-2020 period, the value of the washout increased by $0.94 in the model using corn price data and by $1.54 in the model using soybean price data. This is a 56% and 80% increase, respectively.

By changing the length of optionality, it becomes clear that time is a very important factor that can have a huge impact on the value of these contracting provisions. This supports the idea that more flexibility makes an asset, like these contracts, more valuable. Increasing the time period of optionality increases the value of these contract practices.

5.4.4. Number of Origins

Sensitivity analysis was also completed on the number or origins available for the Chinese buyer to switch to. In regards to a contract washout, the buyer would always be open to switch to any origin. After the default on their contract, they are completely free to re-engage with a seller from anywhere around the world. However, in the case of the origin switching option that is embedded in a contract, the number of available origins is up to negotiation. The base cases allow the buyer to switch to any of four (three) other origins in the corn (soybean) case. However, the number of origins is a term that could be negotiated between a buyer and seller who are embedding this type of option in a contract. To examine how the number of origins available affects the value of the option, a sensitivity analysis model was specified where the buyer only has the option to either remain in their original contract at the U.S. Gulf or to switch to Argentina.

The results of changing the number of optional origins are summarized in Table 5.1 and shown in Appendix A. In the pre-2020 period, changing the number of optional origins from 4 to 1 in the corn model decreased the value of the embedded origin switching option by $0.01.

Similarly, changing the number of optional origins in the soybean model from 3 to 1 decreased the real option value by only $0.02. In the post-2020 period, the value of the embedded switching options changes more drastically. The decrease in the number of optional origins available to switch to decreases the value of the real option by $0.10 in the model using both the corn and soybean price data.

The conclusion is that the more origins that are available to switch to, the more valuable the embedded switching option is. This aligns with real option theory, as more flexibility in future periods should provide more value. However, it is interesting to note how this relationship between the number of optional origins and real option value changes based on the data used for the model. In the less volatile pre-2020 period, changing the number of origins available had a very small impact on the option value. However, this change was more pronounced in the more volatile post-2020 period.

5.5. Further Analysis: Option Value Sharing Parameter

The model results presented above are the mean values of these contracting practices. When these provisions are utilized, they provide value to the contracting parties. This thesis focuses on how buyers can receive value from utilizing these contracting practices to switch geographical origin. However, in both the contract washout and embedded origin switching cases, the grain seller receives compensation for allowing origin switching to occur-- in the embedded origin switching case the seller receives a premium and in the contract washout the seller is compensated by imposing contract cancellation costs to be paid by the buyer, who is the defaulting party. From the buyer's perspective, they can either negotiate a premium to be paid to embed the right to switch in the original contract or face punitive cancellation fees when executing a contract washout ex post.

If the buyer and seller agree to embed an origin switching option into the original contract, they must negotiate the amount of the premium to be paid by the buyer to the seller in exchange for the right to switch origins. It is not immediately clear how much the buyer should pay for this right. The models calculate how valuable this option is to the buyer, and the buyer likely must share a portion of this value with the seller.

One potential method to quantify how much the buyer should pay as a percentage of the option's value is a concept called Shapely values. This concept is from cooperative game theory and was developed by Lloyd Shapely (Roth 1988). The calculation determines the fair distribution of coalition benefits based on each player's contribution. Grain buyers and sellers cooperate to embed origin switching options in the original contract. The fair distribution of the mean value of the embedded origin switching option is calculated using the Shapely value formula:

$$\varphi_i(v) = \sum_{S \subseteq N i} \frac{|S|!\,(n-|S|-1)!}{n!}\left[v(S \cup i) - v(S)\right] \tag{5.1}$$

where *N* is the set of all players, *S* is the subset of *N* that does not include player *i*, and *v(S)* is the value function that gives the total worth of all players in subset *S*. Equation 5.1 calculates the Shapely value for each player. These values are interpreted as percentages of the sum of all player's Shapely values.

To calculate the Shapely values and derive a fair sharing parameter, we first need to identify the individual contributions of each player to the coalition and the total value of the coalition. The total value of the buyer and seller collaborating is the mean value calculated by the embedded origin switching option model. The value of the buyer acting alone is the value of the contract washout model. The value of the seller acting alone is the value of them being able to keep the buyer locked into a contract with no ability to switch origins. This is equal to mean switching value in the models. Using these inputs and equation 5.1, a solution is identified.

In the base case model using corn price data from pre-2020, the value of the embedded origin switching option was determined to be $0.50. The washout using the same data is valued at $0.46. The switching value in the models is $0.30. Given these inputs, the shapely values are determined to be $0.33 for the buyer and $0.17 for the seller. This means that the $0.50 of value from collaborating to embed the switching option in the original contract should be shared with 66% going to the buyer and 34% going to the seller. This is shown in Table 5.2.

Table 5.2. Shapely Value Solution using Corn Pre-2020 Values

Coalition S	**Coalition value v(S)**	**SV Solution**
Buyer	46.00	33.00
Seller	30.00	17.00
Coalition	50.00	50.00

This is an example of how buyers and sellers could fairly share the value of working together to embed an origin switching option in a grain contract. There may be other ways for firms to negotiate the premium of embedded origin switching options, but they are not explored in this thesis as it is not the focus of the study.

5.6. Strategic Interpretation

The base case models display the mean values of these contracting practices. The sensitivity analyses isolate the important variables and demonstrate how they impact the value of the real options. The outputs demonstrate the mechanisms of the model. However, the results must be meaningfully interpreted.

The mean values calculated in these models show that these contracting provisions have significant value. Admittedly, these values are even higher than intuitively thought, especially in the post-2020 period. This is due to the persisting period of high price volatility and weaking correlation among geographical origins. The higher values indicate that the buyer has a higher chance of profiting from the contract practice, which is due to the more volatile prices at origins where prices are moving together to a lower degree. Because incentives to switch are more prevalent, the seller would demand a higher premium, as a portion of the value of the contract practice.

Stepping back from these hypothetical situations driving the models, these results have implications for the real world. Contract washouts and embedded origin switching options are important to international trade and can have significant value as proven in the models. There are several factors that impact this value, most pertinently the price volatility.

The most impactful conclusion is seen in analyzing the differences between the pre-2020 and post-2020 periods. Across all the models, including both the embedded origin switching options and the contract washout models and using both corn and soybean price data, there is a significant increase in the mean values of these contracting practices in the more recent post-2020 period. This helps explain the increase in the occurrence of contract washouts and optional-origin contracting. The biggest difference between the pre-2020 and post-2020 periods is the volatility of grain prices, which is driving the value of the contract provisions higher. There are other important factors, which are explored in the sensitivity analyses.

Currently, contract washouts are likely more common. Large grain buyers who are able to default on their contracts without permanently damaging their trade relationships can execute contract cancellations and fulfill their grain needs from a cheaper origin. However, it is foreseeable for buyers who aren’t able to execute washouts to negotiate embedded origin switching options into their contracts. If a seller agrees to provide this optionality, they can better plan for the future grain flows through their value chain. Plus, the seller receives a premium for offering the buyer such flexibility.

5.7. Summary

This chapter delves into the results of the model. This thesis studies two relatively novel contracting practices: embedded origin switching options and contract washouts. To illustrate these, base case models are specified, which are meant to be representative of how these practices are used in international grain contracts. The results of these base cases show that both contract washouts and embedded origin switching options can have significant value. Sensitivity analysis on the most relevant factors reveal the causes of this value. Increased time of optionality and volatility lead to larger real options values, along with decreased correlation among prices at different geographical origins.

The sensitivity analysis results help explain the recent elevated occurrence of contract washouts and embedded origin switching options, which is documented in Chapter 2. The price data used in the models are separated into two periods: one before June 5, 2020 and the other after. Summary statistics show that volatility significantly increased in the post-2020 period and correlations changed. These changes in price behavior led to increased real option value, as displayed in the results of the models. If this period of higher volatility and lower correlation continues, contract washouts and embedded switching options are expected to become more common.

The results of the thesis research are presented and analyzed in this chapter. The models, as specified in the previous chapter, produce results that have implications for the grain trading industry. These conclusions are discussed more thoroughly in the following chapter.

6. CONCLUSION

6.1. Introduction

Previous chapters in this thesis have introduced the topic of study, which is contract washouts and embedded origin switching options. These contract practices are defined and related past studies reviewed. Contract washouts occur when grain buying firms cancel their original contracts to buy grain and subsequently buy back similar quantities of grain from a cheaper origin. Alternatively, some firms negotiate an embedded origin switching option into their original grain contract, which gives the buyer the right to switch the origin of grain at a later date. Real option methodology is discussed as a theoretical framework to value these practices. Using this framework, an empirical model is developed using corn and soybean price data from the past five years. The model involves several base cases, which are defined to be the most representative of industry practice. The results of the models are presented and analyzed, which includes sensitivity analysis.

This chapter provides the conclusions of the study. It begins with a review of the purposes and objectives of the thesis. Then, notable results of the models are reviewed and summarized, and the strategic implications of the research are discussed. Finally, the limitations of the study and its contributions to the literature are presented before suggestions for future research related to this topic are given.

6.2. Review of Purpose and Objectives

In the introductory chapter of this thesis, the purpose of the study is defined and several research objectives are established. The goal of the study is to investigate two relatively novel contract practices that are occurring in the grain trading industry. Because both contract washouts and embedded origin switching options are new, they have not yet been studied. Grain trading firms need to learn how to value these practices so that they can optimally manage their grain contracts. Thus, specific objectives include defining contract washouts and embedded origin switching options and providing distinctions between the two, documenting the many occurrences of these contract practices, and proposing a quantitative method to value them.

These objectives are accomplished throughout this study. The definitions of these terms are introduced first in Chapter 2 and developed throughout the entire body of work in this thesis. Contract washouts are defined as contract cancellation followed by a switch to another origin. Embedded origin switching options are a contract term negotiated into the original contract that gives the buyer the right to switch the origin of their grain at a later time period. Table 2.2 contains a comprehensive but not exhaustive list of contract washouts and embedded origin switching options documented in the industry trade. This documentation lends itself to both the definitions of the terms themselves and the base cases meant to represent them. Chapters 3 and 4 outlay the proposed quantitative method for valuing contract washouts and embedded origin switching options. Real option methodology is used to create a framework to model the flexibility and managerial optionality that these contract practices provide. This methodology guides the development of empirical models based on hypothetical base case assumptions. The base case models help illustrate the most representative scenarios in which these contract practices are used in the grain trading industry. The results of these models have strategic implications for the grain trading industry.

6.2.1. Summary of Results

There are several models developed in order to accomplish the purposes and objectives of this thesis. Specifically, eight base case models are developed, along with 28 sensitivity analyses. There are two model types: embedded origin switching option models and ex-post contract washout models. The first uses a switching-type real option while the second is a compound option combing cancellation and switching-type real options. There are eight base case models by using four different datasets for each of the two main model types: corn pre-2020, corn post-2020, soybeans pre-2020, and soybeans post-2020. Sensitivity analysis is conducted on each of the eight base case models for volatility, correlation, and time of optionality. Additionally, for the embedded origin switching option models, sensitivity analysis is performed on the number of optional origins. The results from the models are discussed in depth in Chapter 5, but the most notable results are reviewed here as well.

6.2.1.1. Notable Base Case Results

The models in this thesis show that both contract washouts and embedded origin switching options have significant value. These values are shown in Table 6.1. For example, the contract washout is valued at $0.88 for soybeans in the pre-2020 period. This is the mean value of washing out of a contract. Since a washout is executed ex-post, the grain buyer would only cancel and switch if there is a spatial arbitrage opportunity. While there could be costs associated with doing this, the mean value shows that there are many opportunities where the benefits would outweigh the costs. Thus, grain buyers who are poised to execute washouts could profit.

Table 6.1. Base Case Results

Embedded Origin Switching Option				
	Corn Pre-2020	Corn Post-2020	Soybeans Pre-2020	Soybeans Post-2020
Mean	$0.50	$1.77	$0.90	$2.03
St. Dev	$0.11	$1.28	$0.45	$0.40
Contract Washout				
	Corn Pre-2020	Corn Post-2020	Soybeans Pre-2020	Soybeans Post-2020
Mean	$0.46	$1.67	$0.88	$1.93
St. Dev	$0.11	$1.28	$0.43	$0.42

These contracting provisions have become much more valuable in the more recent period, as seen when comparing the model results from the pre-2020 period to the results from the post-2020 period. The embedded origin switching option value increased by 254% for corn and 126% for soybeans. The contract washout value increased by 263% for corn and 119% for soybeans. Given that this post-2020 period is characterized by much higher price volatility and changing correlation between geographical origins, this increase in option value makes intuitive sense.

Volatility and correlation are isolated in the sensitivity analyses to see how changing these variables affects the option value. The sensitivity analyses confirm that the much higher volatility in the post-2020 period is the most likely cause for the increased value of both the contract washout and the embedded origin switching option.

6.2.1.2. Notable Sensitivity Results

Sensitivity analysis isolates important factors in order to examine the impact of changes in the variables on the output results. Volatility, correlation, time of optionality, and the number of optional origins (for embedded origin switching options) are chosen as variables for such analysis. The most important conclusion from the sensitivity analysis is the direction of the change in the value of the contract practices given a change in the relevant variables. These directional relationships are summarized in Table 6.2.

Table 6.2. Sensitivity Analysis Relationships

Variable	**Change**	**Option Value**
Volatility	↑	↑
Correlation	↓	↑
Time	↑	↑
# of Origins	↓	↓

Additionally, the magnitude of the changes resulting from sensitivity analysis should be noted. Volatility and correlation affect the option value by only a few cents when allowed to vary only slightly around the mean (+/- 10%). However, when this variation is increased, the option value changes more significantly. The length of time of the optionality is shown to be an important factor as well. As the time of optionality increased, so did the option value. The number of optional origins specified in the embedded origin switching option had a large impact on the models using the post-2020 data, but the change was much smaller in the pre-2020 models. This is likely due to changes in the dataset that make more optionality more valuable.

The results from the models in this thesis are quantitatively arbitrary since they are built for a hypothetical scenario. Nonetheless, the values calculated depict the industry practices. The results highlight several important concepts, and there are qualitative implications of the model outputs.

6.3. Implications of Results

This study analyzes two contract practices currently becoming more and more common within the grain trading industry. A thorough review of industry news reports indicated this fact: contract washouts and embedded origin switching options are occurring more frequently. This motivates this thesis. The models are built to derive the value of these contract practices.

Results clearly indicate that the contract practices have significant value to the buyers who are executing them. The exact value is dependent on several factors, such as the price volatility, correlation among international grain origins, the time of optionality, and the number of optional origins. These factors can change significantly, which is shown in the differences between the data in the pre-2020 period versus the post-2020 period, as defined in Chapter 4.

The differences explain the large increase in the value of the contract provisions in the post-2020 period when compared to the pre-2020 period.

The findings of the model have important implications for grain industry participants. Given how valuable these provisions can be to buyers, their use is expected to continue to increase. Buyers are incentivized to find sellers who offer this optionality, whether embedded into the contract or ex-post in a washout. Large buyers who have market power may be better off using ex-post contract washouts. However, smaller buyers who are unable to demand ex-post negotiations should look for sellers willing to embed an origin switching option into the original contract. Sellers who do offer optional-origin provisions have to strategically manage the terms of the provision, such as time and number of optional origins, as well as monitor current price behavior variables like volatility and correlation. Nonetheless, they may have incentive to embed the option in the original contract as it will allow them to plan for grain flows through their supply chain. Additionally, firms must decide how to share the value of these provisions between buyers and sellers. The first step in accomplishing this is determining how valuable the practice is, which can be accomplished using the methodology of this thesis.

6.4. Limitations

Many assumptions are made in creating the models, which are limitations of the research. These assumptions are representative of the most likely scenario in which contract washouts and embedded origin switching options are used. However, there are many situations in which these assumptions may not hold, which could limit the application of the conclusions from this study.

One of the most important assumptions is regarding the cost of switching in the contract washout models. The models are built on the assumption that to cancel their original contract, the grain buyer must simply pay the difference between the current price and the contracted price. In reality, different firms may handle contract cancellations differently. The cost of the switch is a very important consideration in calculating the value of the washout.

Another limitation is the disregard of other factors relevant to the decisions to switch origins, which include grain quality, logistical concerns such as wait times, and politics, among others. These factors are harder to model, so the models consider only price differences. Nonetheless, they are important grain firm considerations, so their exclusion may lead to oversimplification of these contracting practices.

6.5. Contributions

The major contributions of this study to the body of work are related to the objectives of the thesis. Because of the relatively novel nature of the contract practices studied, the thesis contributes to knowledge by defining both contract washouts and embedded origin switching options. These terms are buzz words in industry trade, but this thesis sorts through the ambiguity to provide definitive explanations and distinctions. The documentation of occurrences highlights the relevance of this topic to the current state of the grain trading industry.

Additionally, this thesis provides a quantitative way to value these contract practices. This builds on the work of Johansen and Wilson (2019) and Hanson (2020), using real option methodology to value origin switching options. However, this thesis applies the methodology to buyer optionality in contracts. The values outputted by the models explain the increased frequency with which grain buyers are using contract washouts and origin switching options. The sensitivity analysis shows that higher volatility and lower correlation make these contracting practices more valuable. Higher volatility in the post-2020 drives larger real option value from the models using price data from that period. Again, this lends an explanation to the recent frequency of the contract practices studied in the thesis.

6.6. Suggestions for Future Research

The research conducted in this thesis has important implications for the grain trading industry. However, the increasing frequency of contract washouts and embedded origin switching options in international grain contracts necessitates the need for continued research in this area. As these contract practices evolve and change, the dynamics involved should remain a topic of academic interest.

Specific areas that require further inquiry involve many of the limitations of this research. The models could be adjusted in order to account for quality differences between grain originated at different geographical origins. Additionally, transportation risks could be added, which could affect the value of the contracting practices. There are many factors that induce origin switching and many variables that drive its value. This study examined the most pertinent ones, but further research could examine others.

Additionally, other related topics could be studied. The switching option discussed in this study gives the buyer the right to change the geographical origin of their grain. Other switching options could grant the buyer the right to switch the delivery time period or the quality, and these are areas of potential future study.

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APPENDIX

Figure A1. Volatility Sensitivity Corn Embedded Origin Switching Option Pre-2020

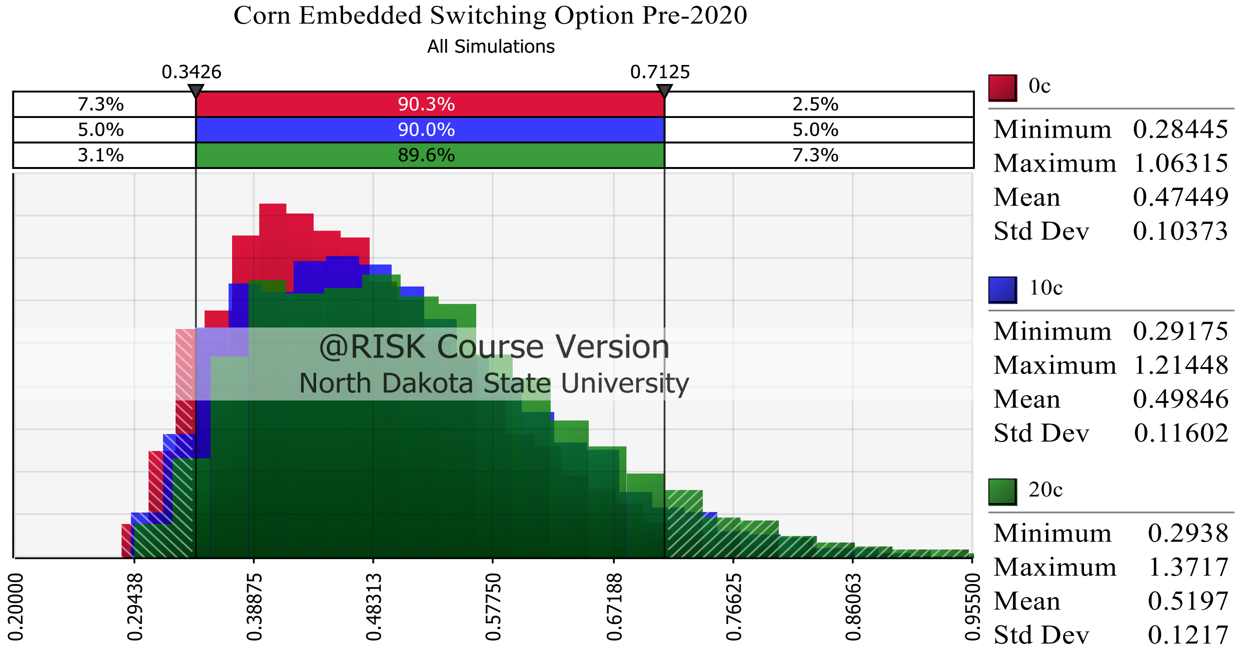

Figure A2. Volatility Sensitivity Corn Embedded Origin Switching Option Post-2020

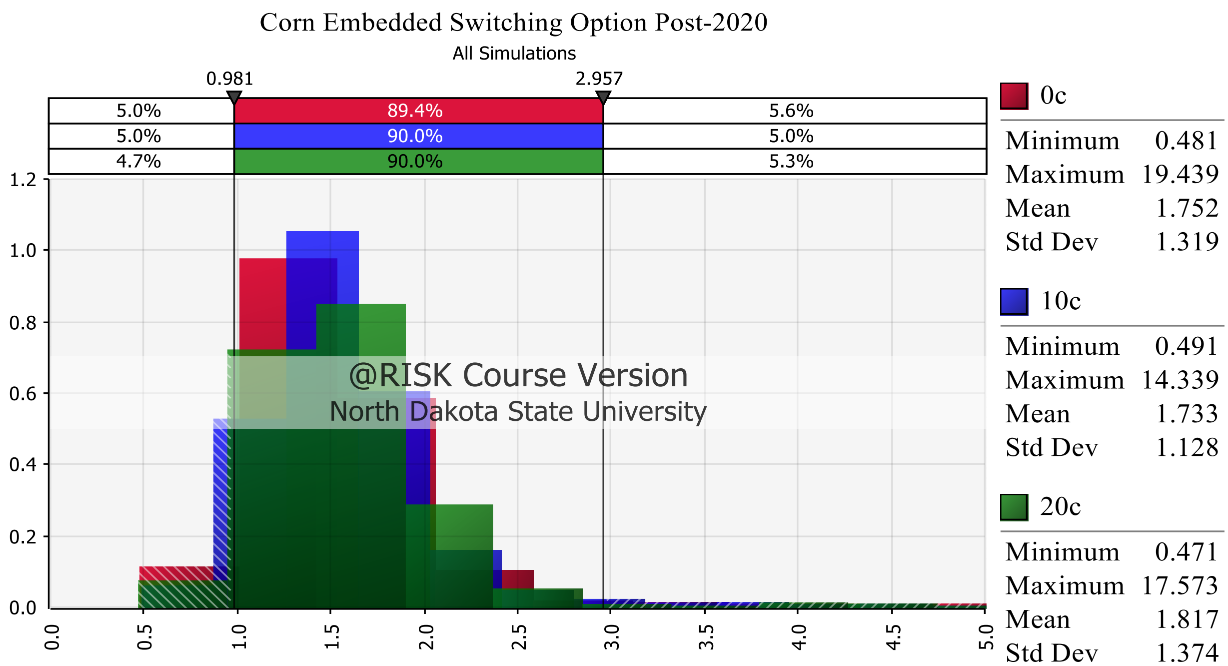

Figure A3. Volatility Sensitivity Corn Contract Washout Pre-2020

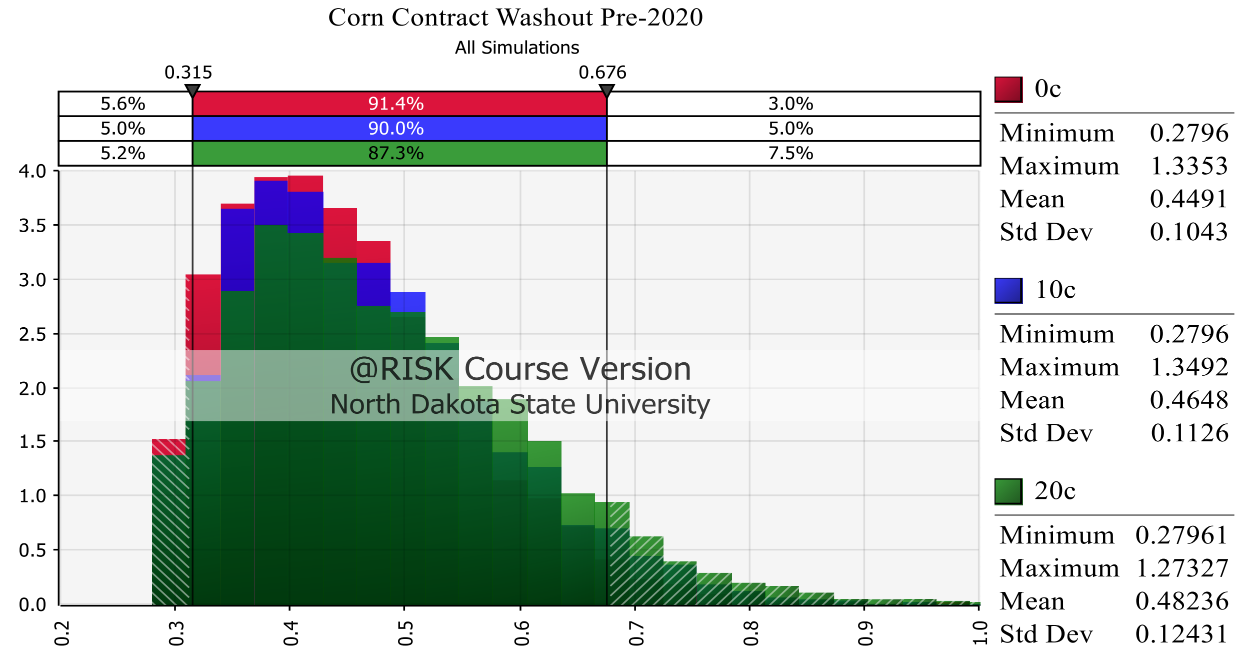

Figure A4. Volatility Sensitivity Corn Contract Washout Post-2020

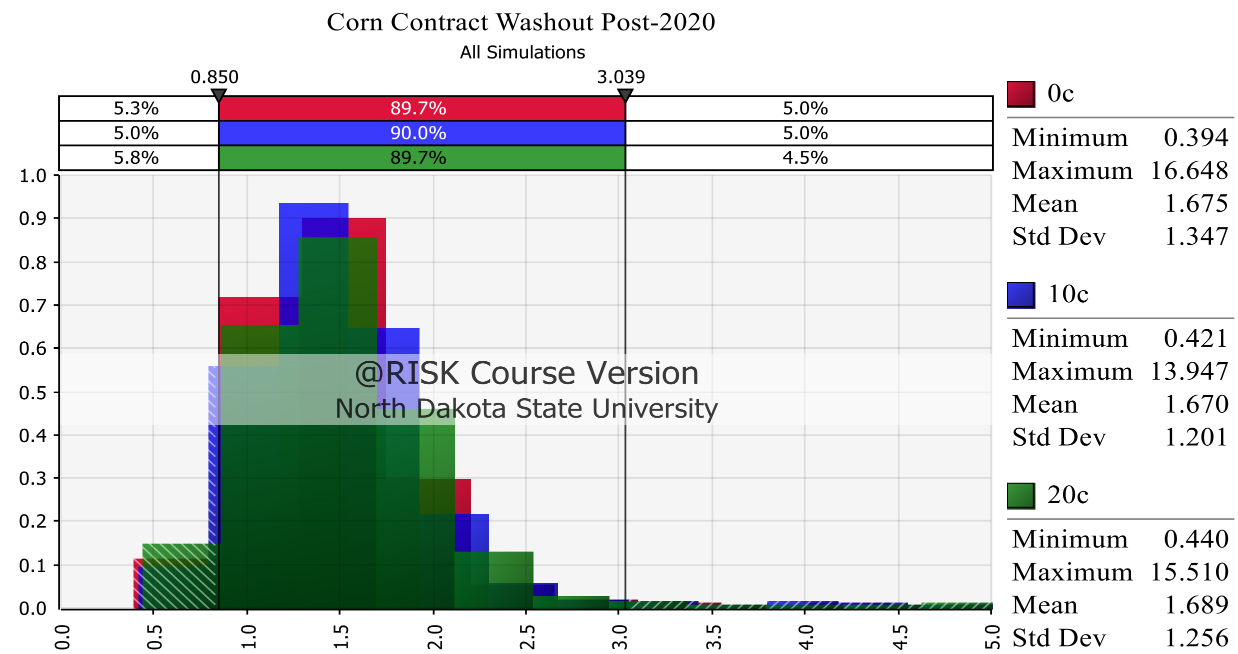

Figure A5. Volatility Sensitivity Soybean Embedded Origin Switching Option Pre-2020

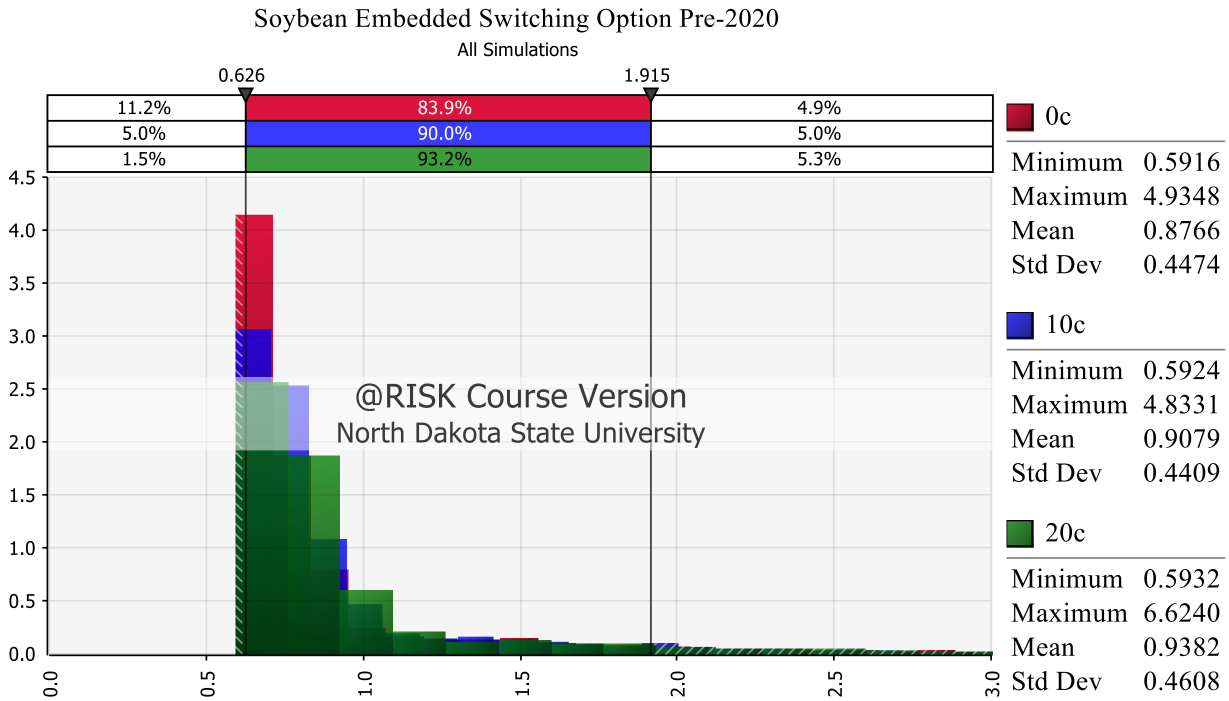

Figure A6. Volatility Sensitivity Embedded Origin Switching Option Post-2020

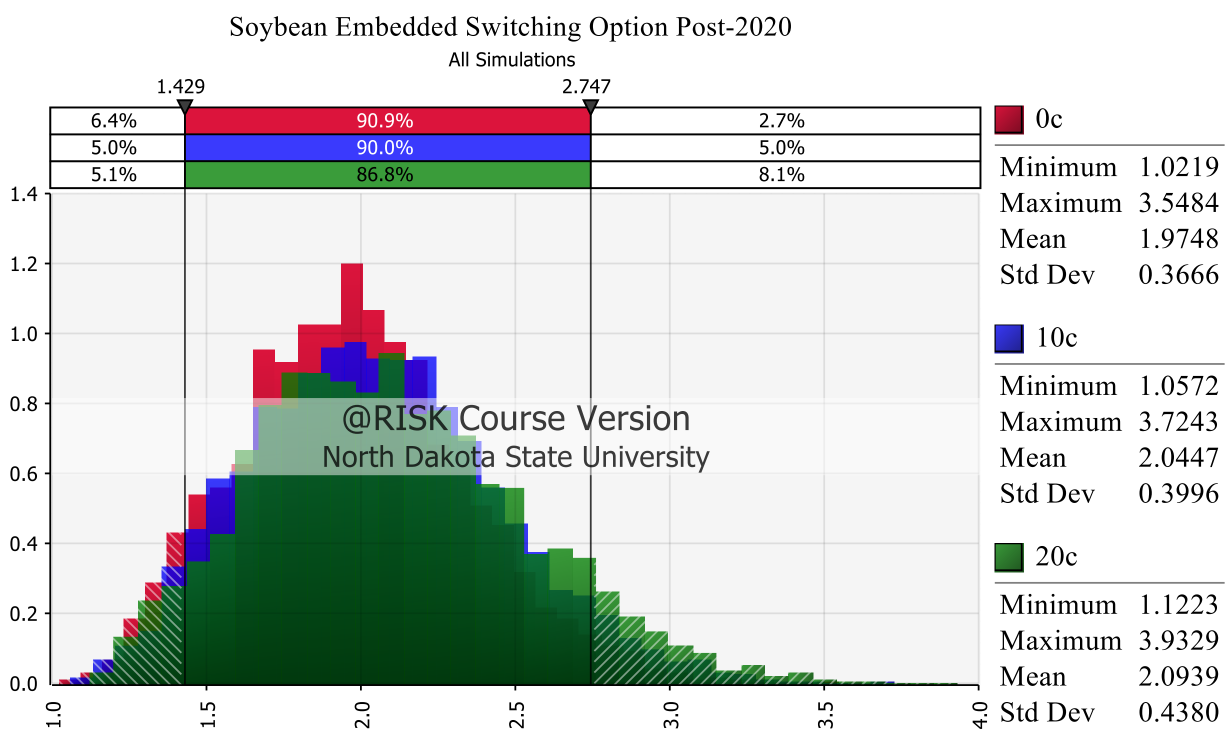

Figure A7. Volatility Sensitivity Soybean Contract Washout Pre-2020

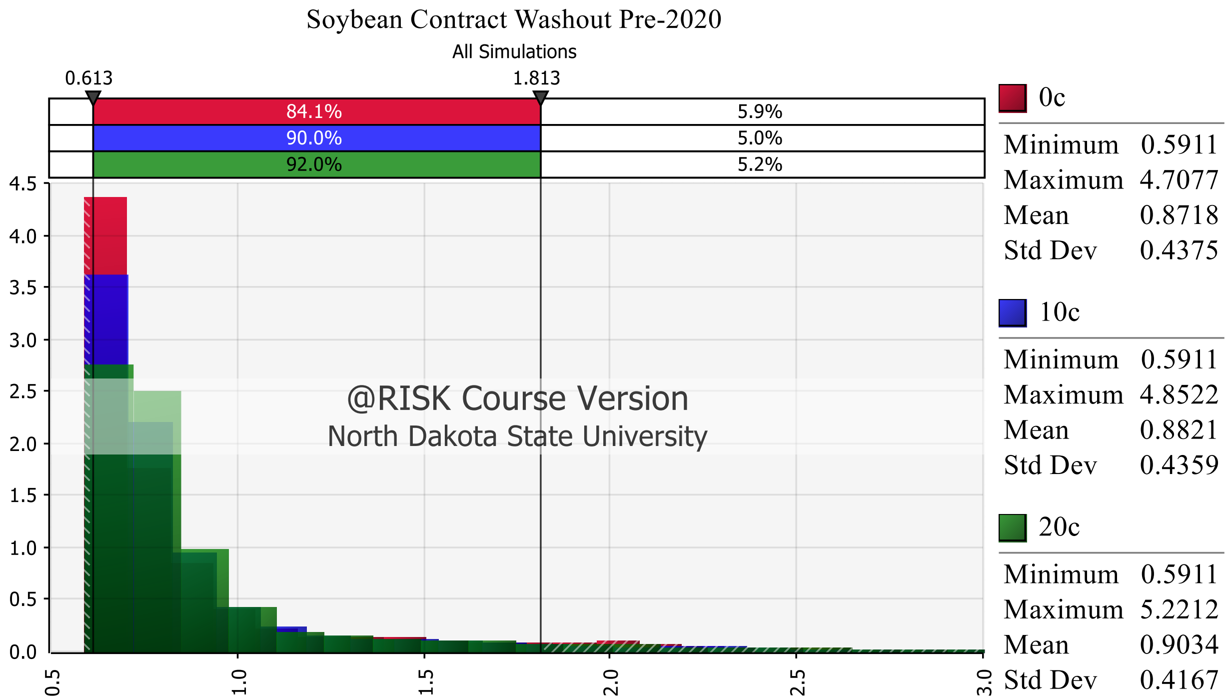

Figure A8. Volatility Sensitivity Soybean Contract Washout Post-2020

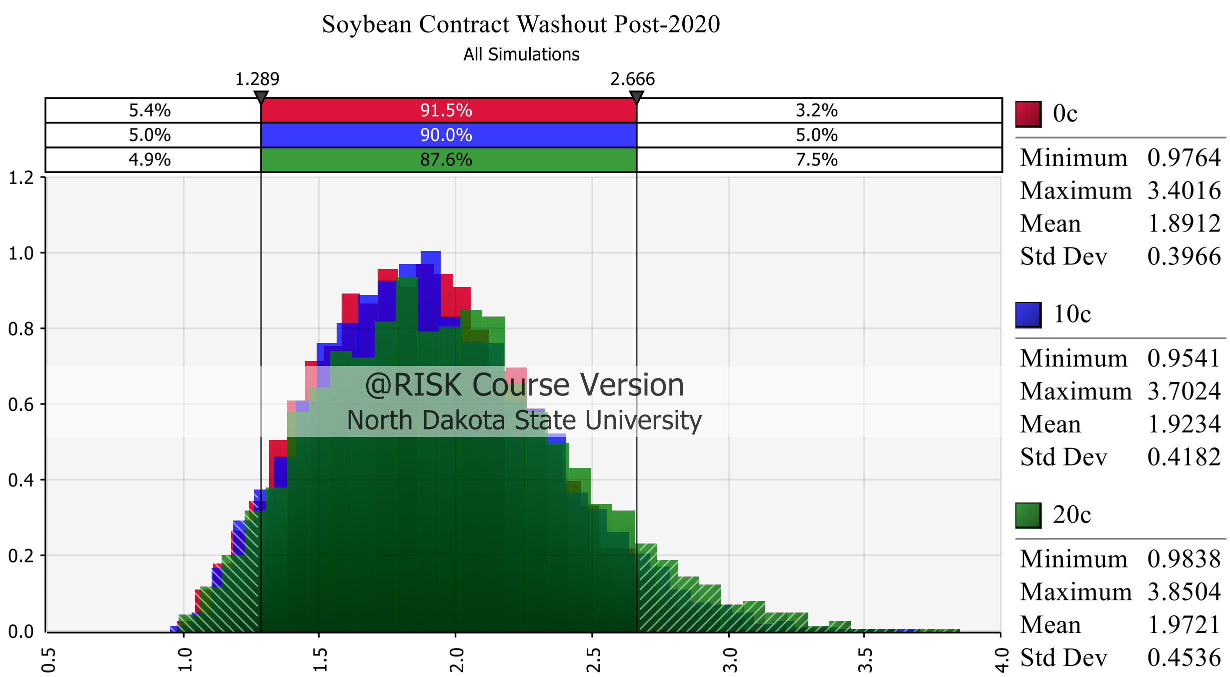

Figure A9. Correlation Sensitivity Corn Embedded Origin Switching Option Pre-2020

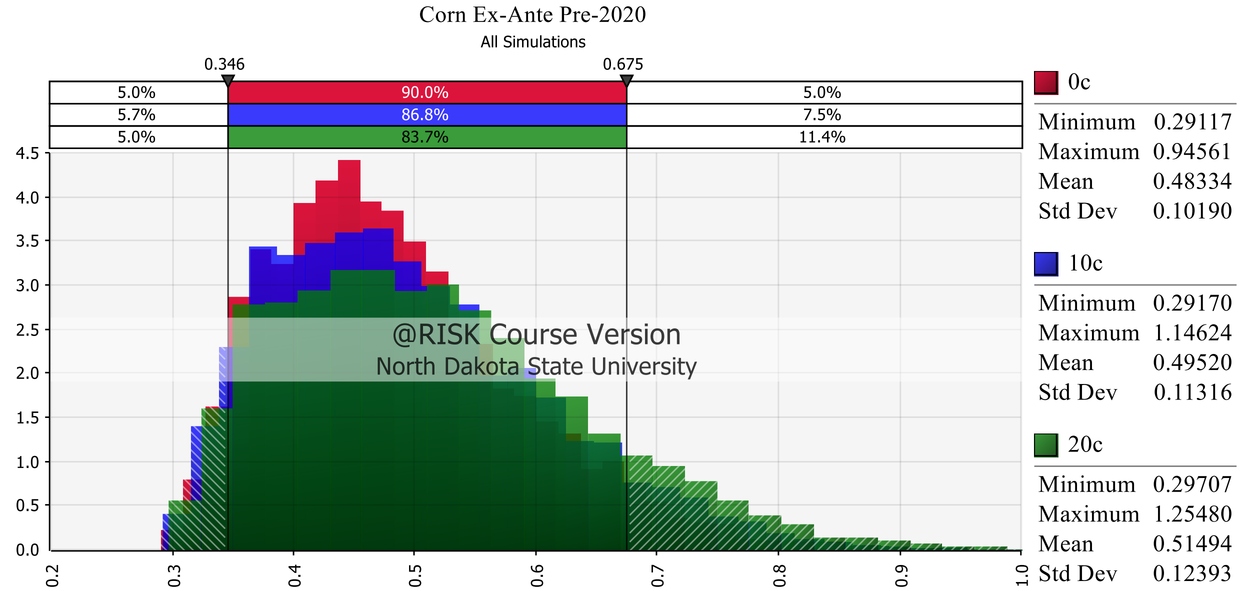

Figure A10. Correlation Sensitivity Corn Embedded Origin Switching Option Post-2020

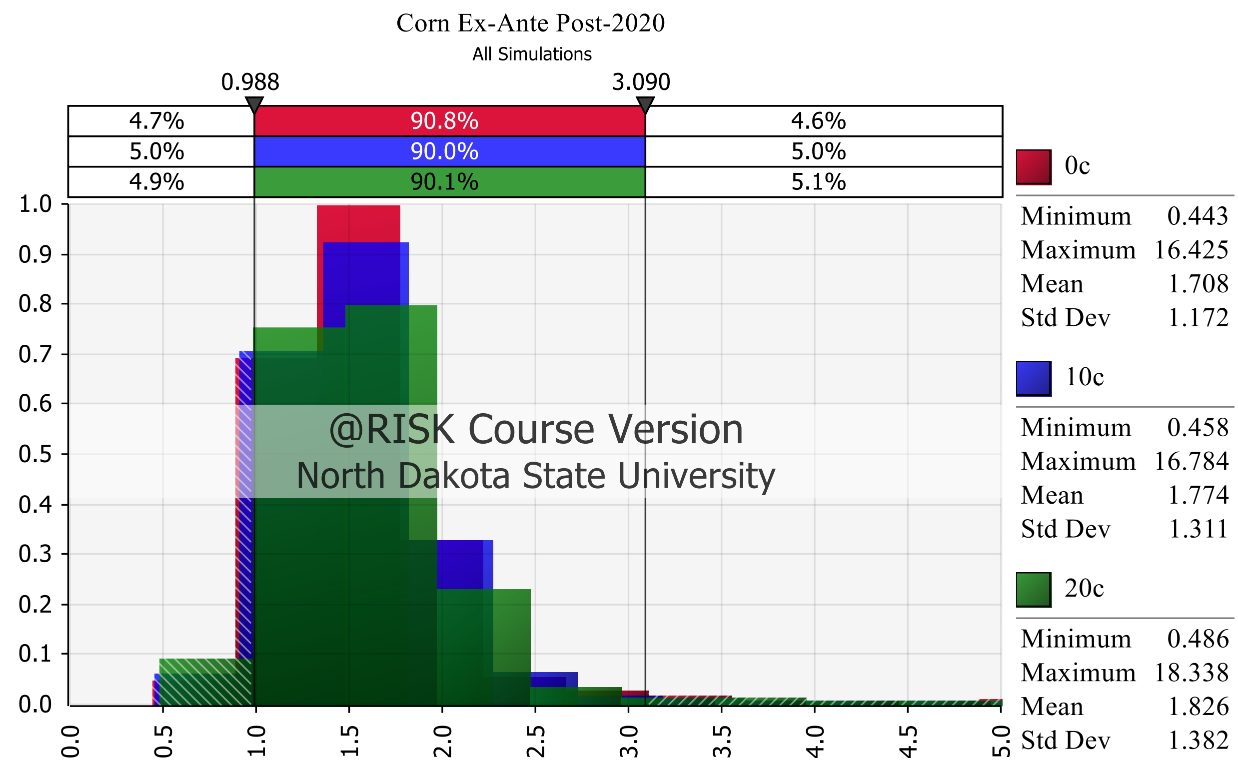

Figure A11. Correlation Sensitivity Contract Washout Pre-2020

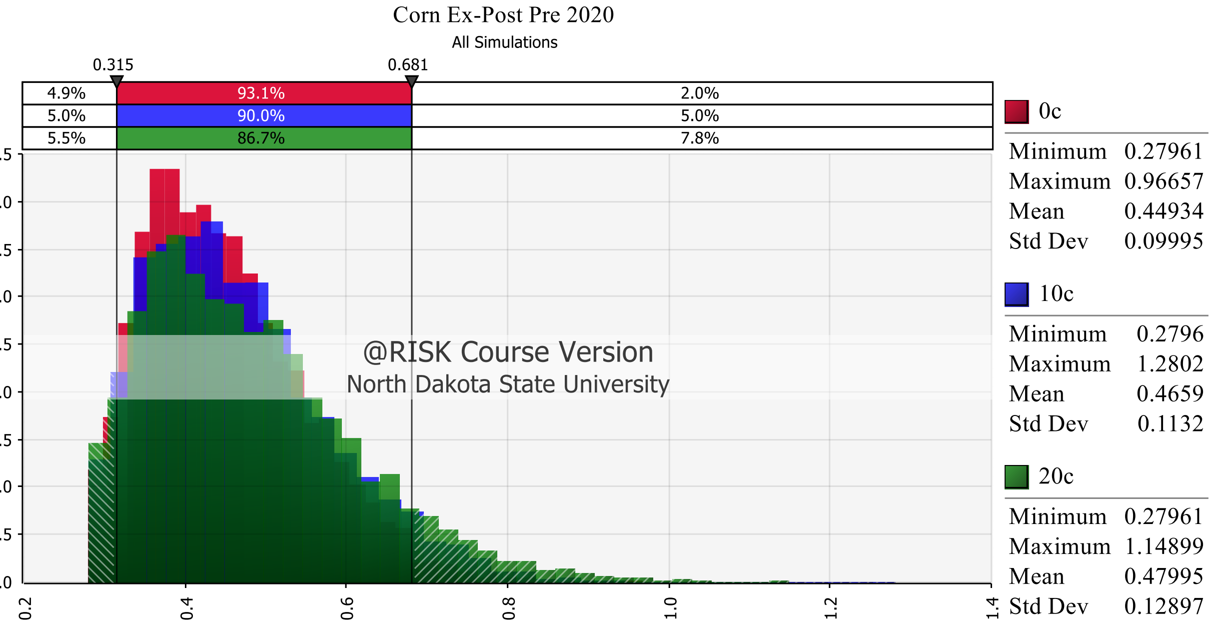

Figure A12. Correlation Sensitivity Contract Washout Post-2020

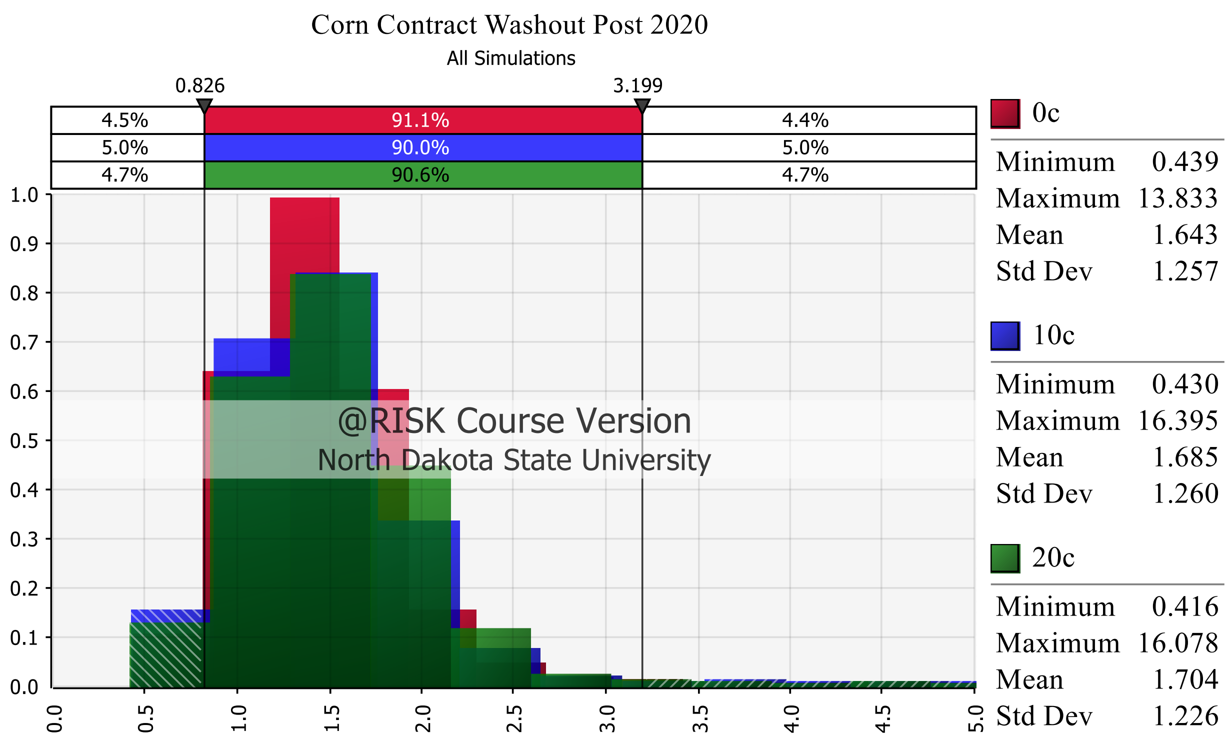

Figure A13. Correlation Sensitivity Embedded Origin Switching Options Pre-2020

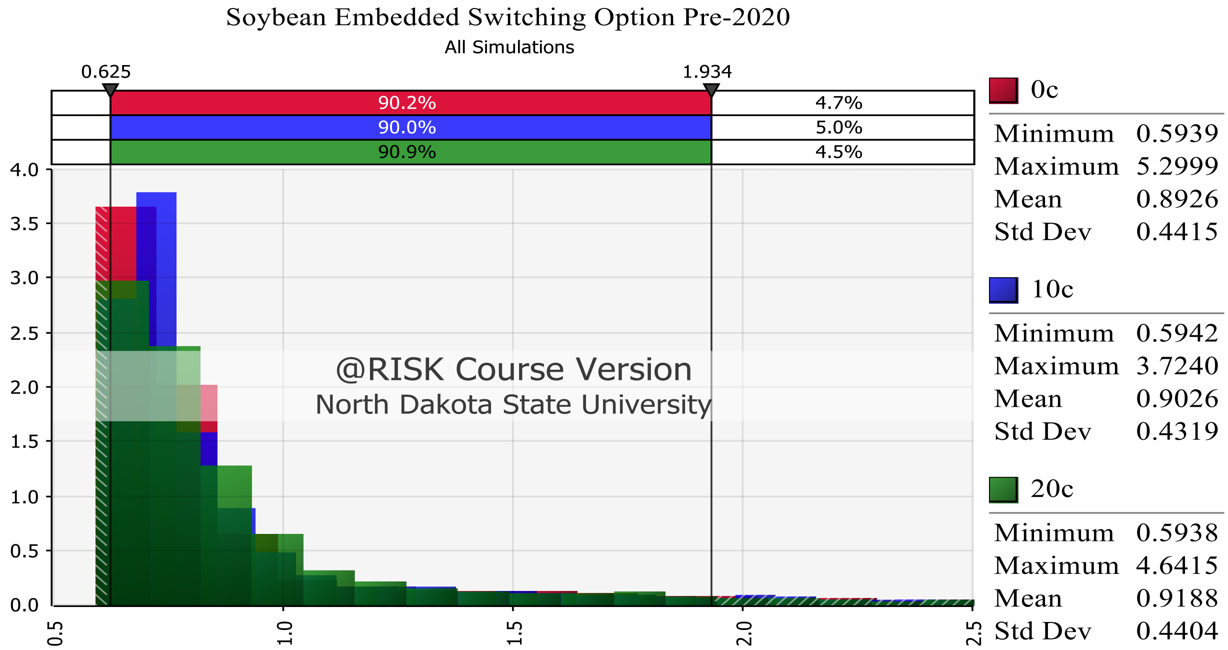

Figure A14. Correlation Sensitivity Embedded Origin Switching Options Post-2020

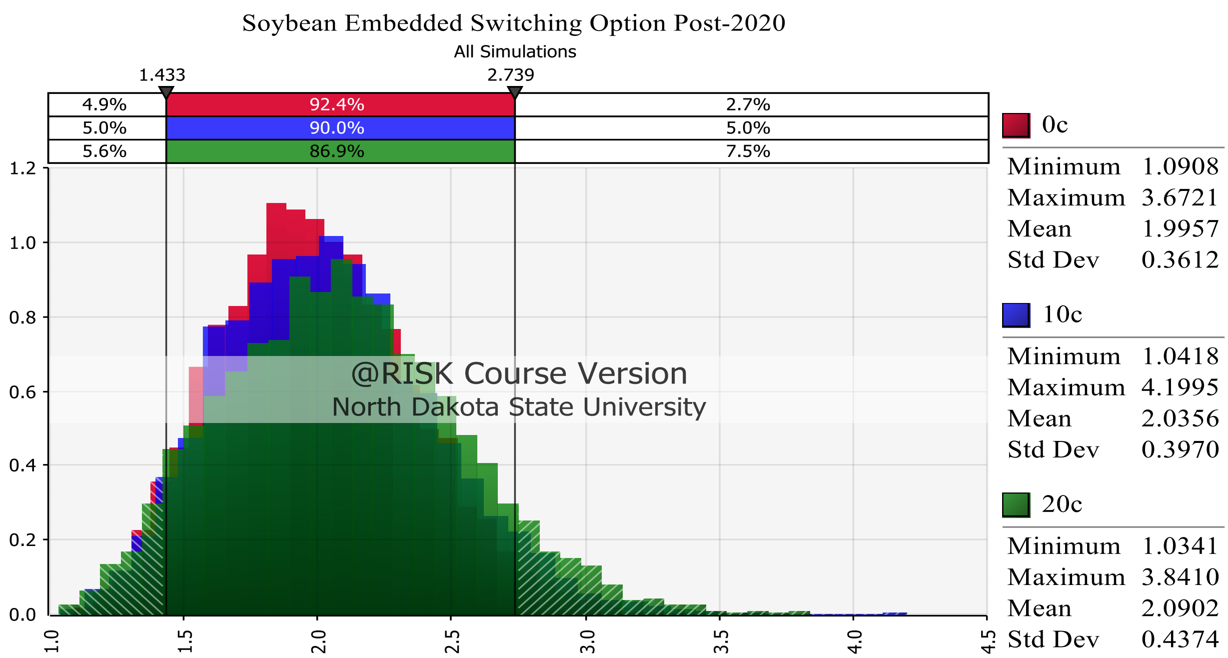

Figure A15. Correlation Sensitivity Contract Washout Pre-2020

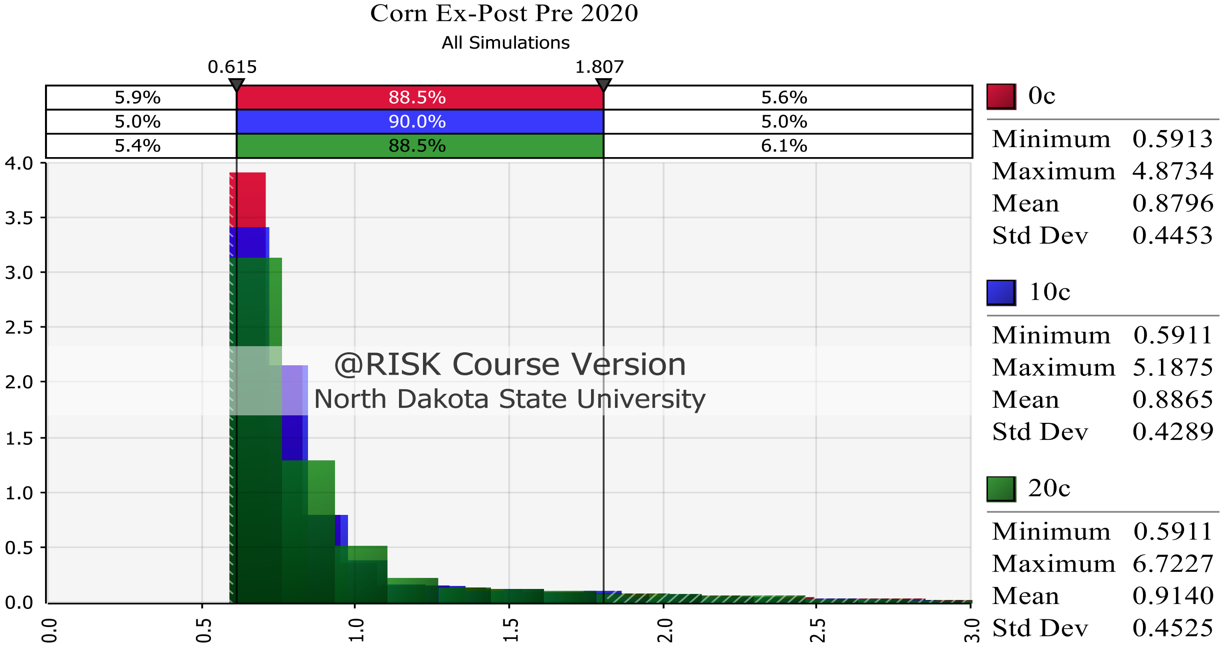

Figure A16. Correlation Sensitivity Contract Washouts Post-2020

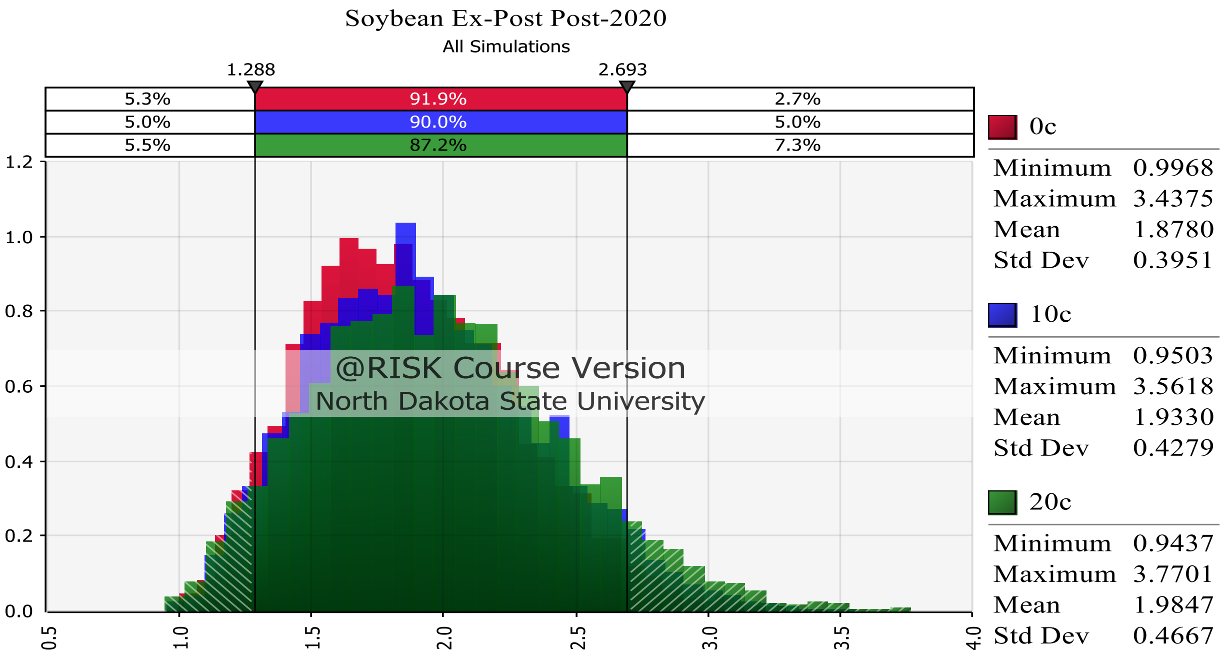

Figure A17. Time Sensitivity Corn Embedded Switching Option Pre-2020

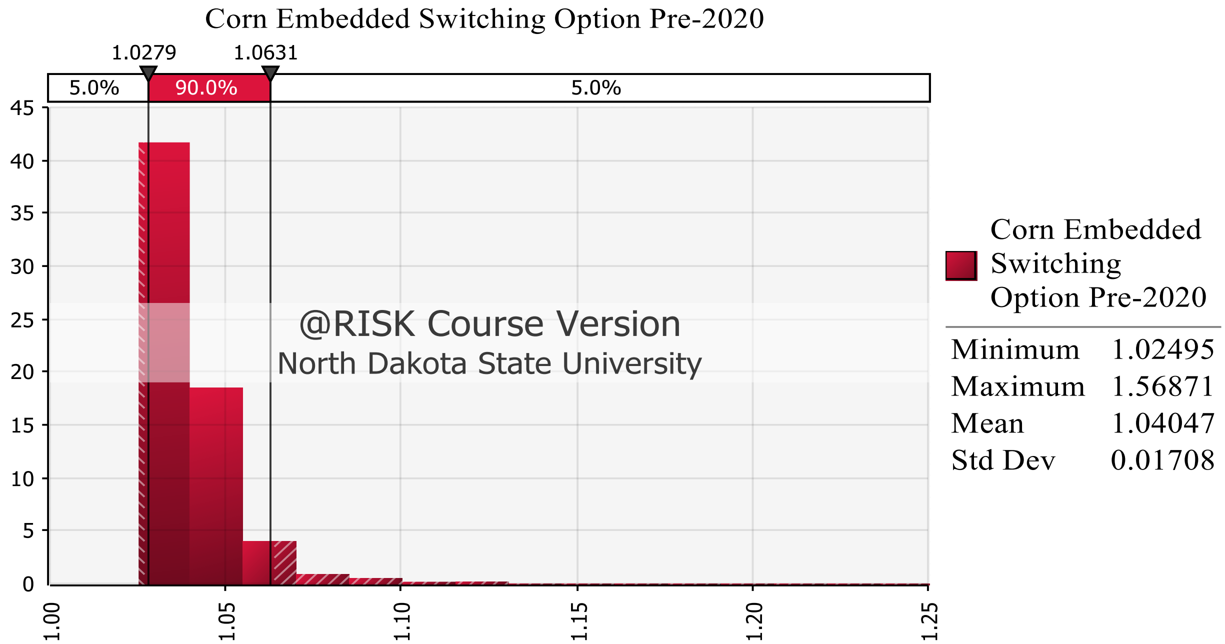

Figure A18. Time Sensitivity Corn Embedded Switching Option Post-2020

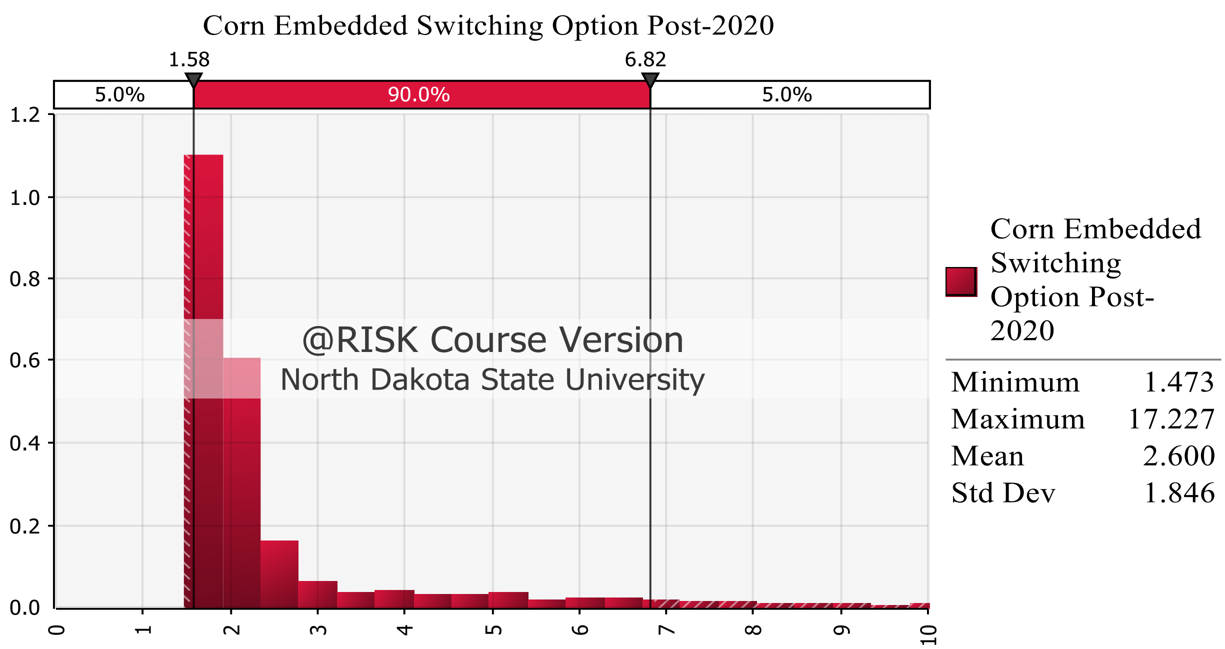

Figure A19. Time Sensitivity Corn Contract Washout Pre-2020

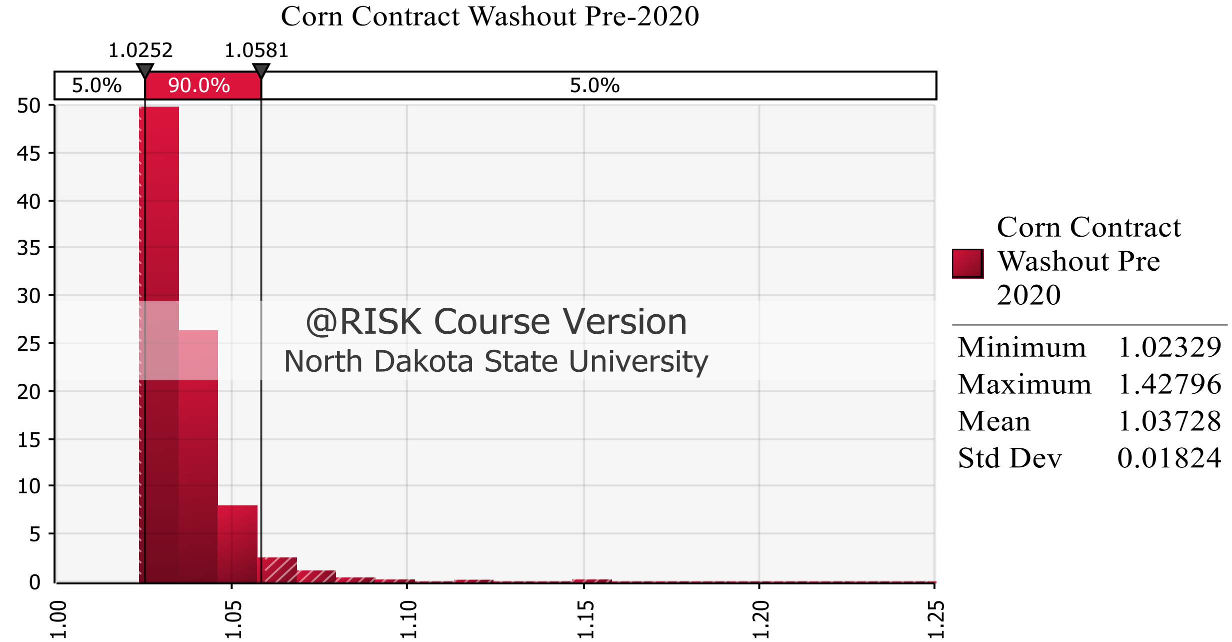

Figure A20. Time Sensitivity Corn Contract Washout Post-2020

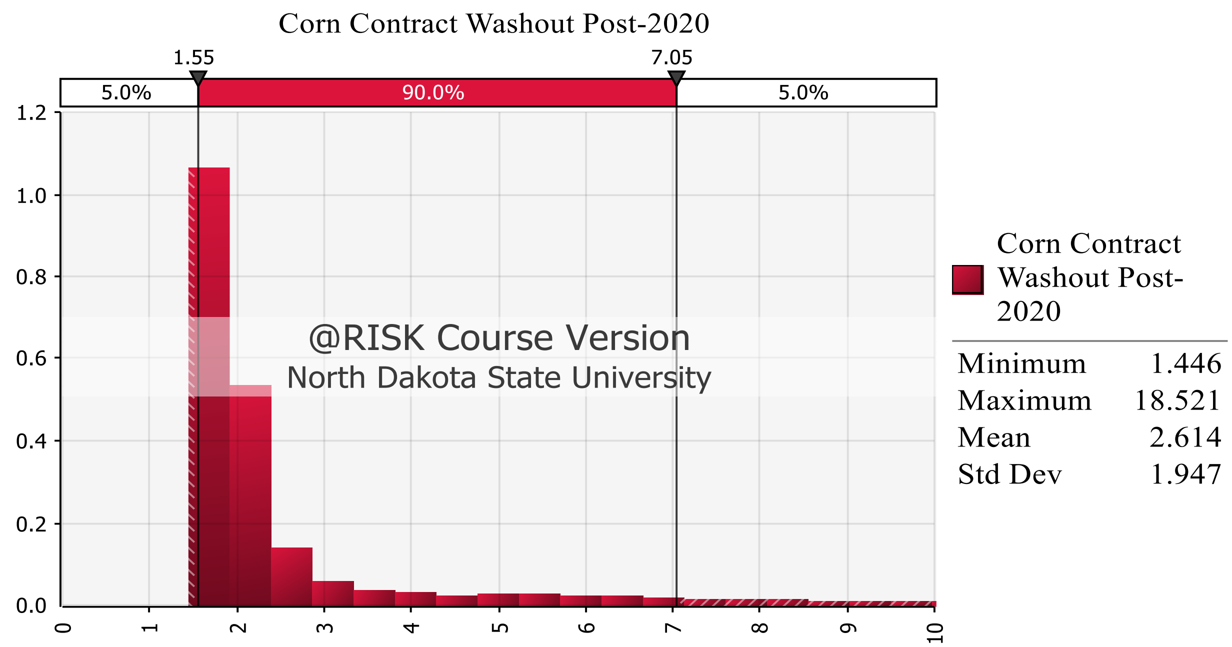

Figure A21. Time Sensitivity Soybean Embedded Switching Option Pre-2020

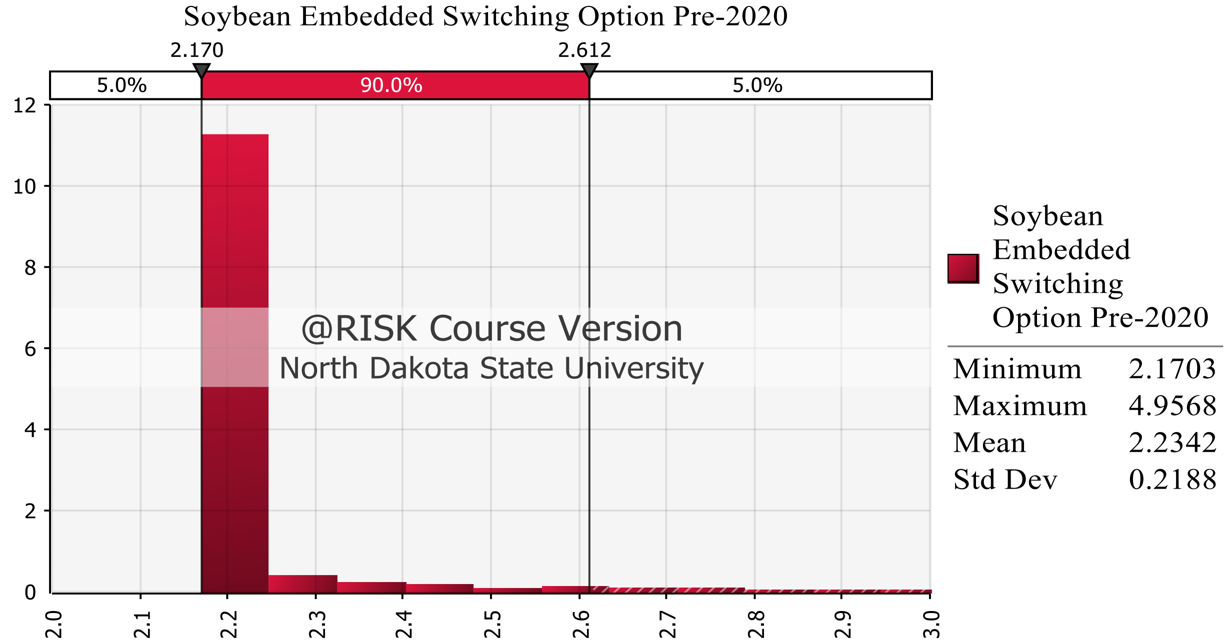

Figure A22. Sensitivity Soybean Embedded Switching Option Post-2020

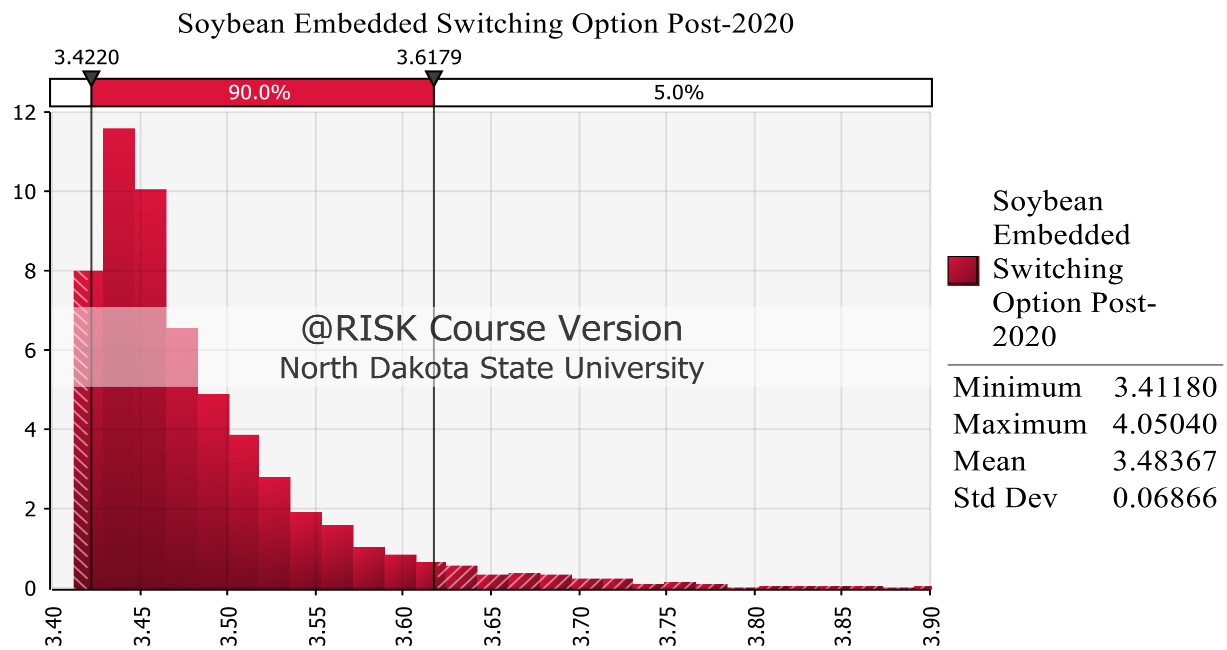

Figure A23. Time Sensitivity Soybean Contract Washout Pre-2020

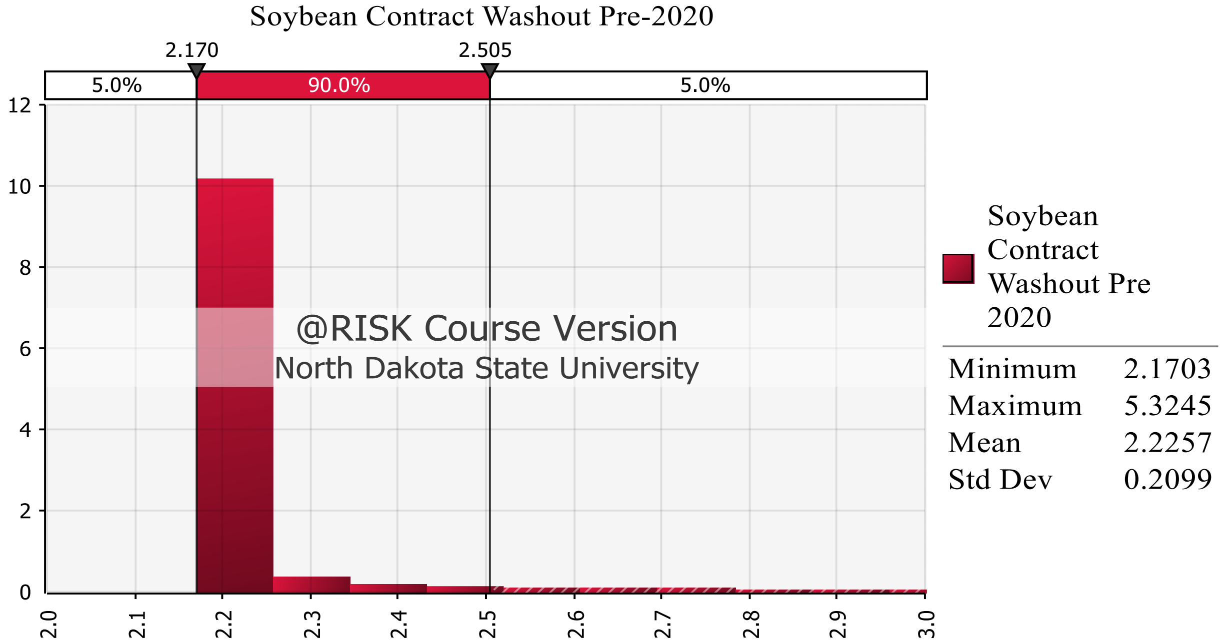

Figure A24. Time Sensitivity Soybean Contract Washout Post-2020

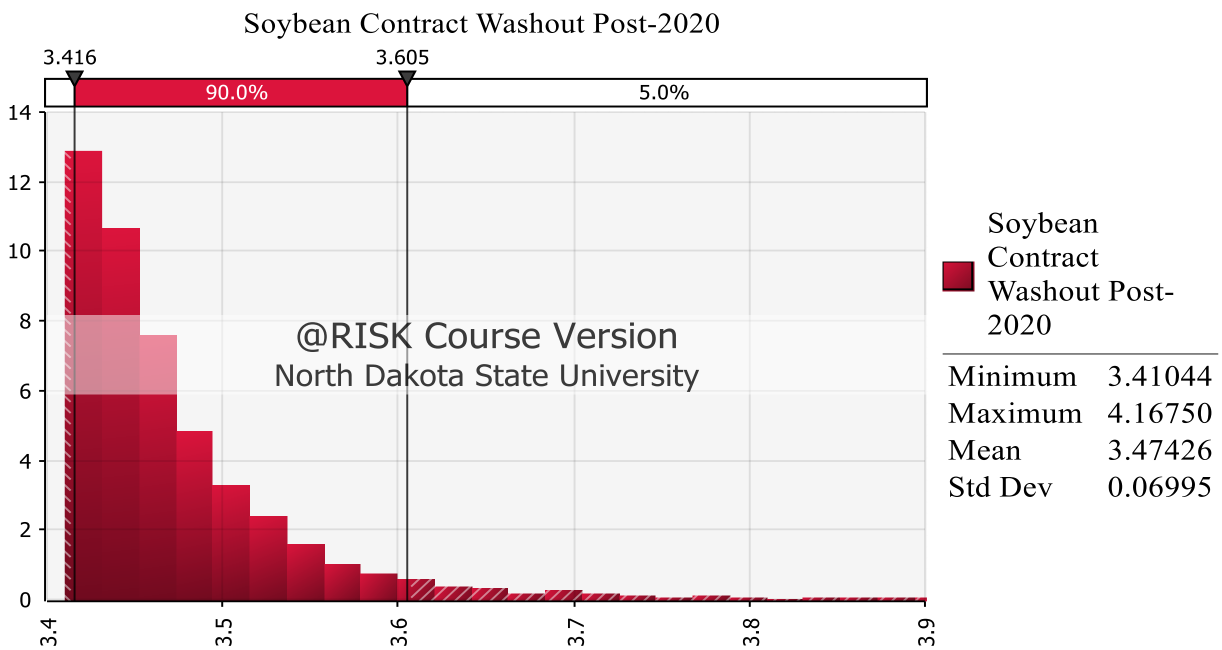

Figure A25. Number of Optional Origins Sensitivity Corn Pre-2020

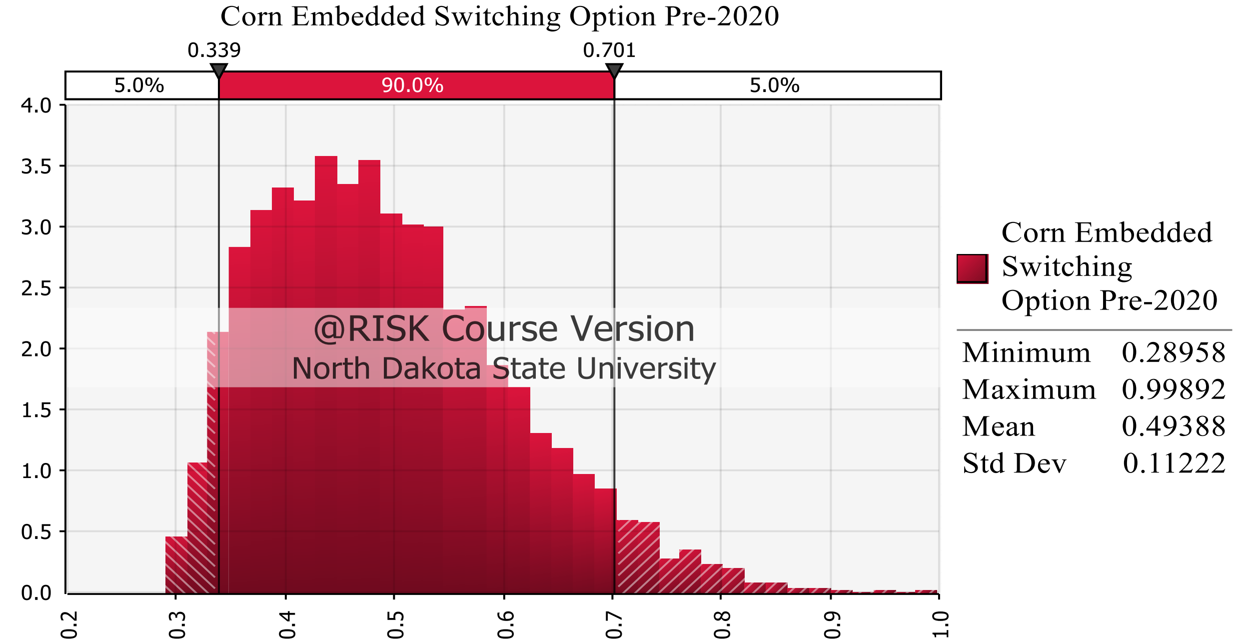

Figure A26. Number of Optional Origins Sensitivity Corn Post-2020

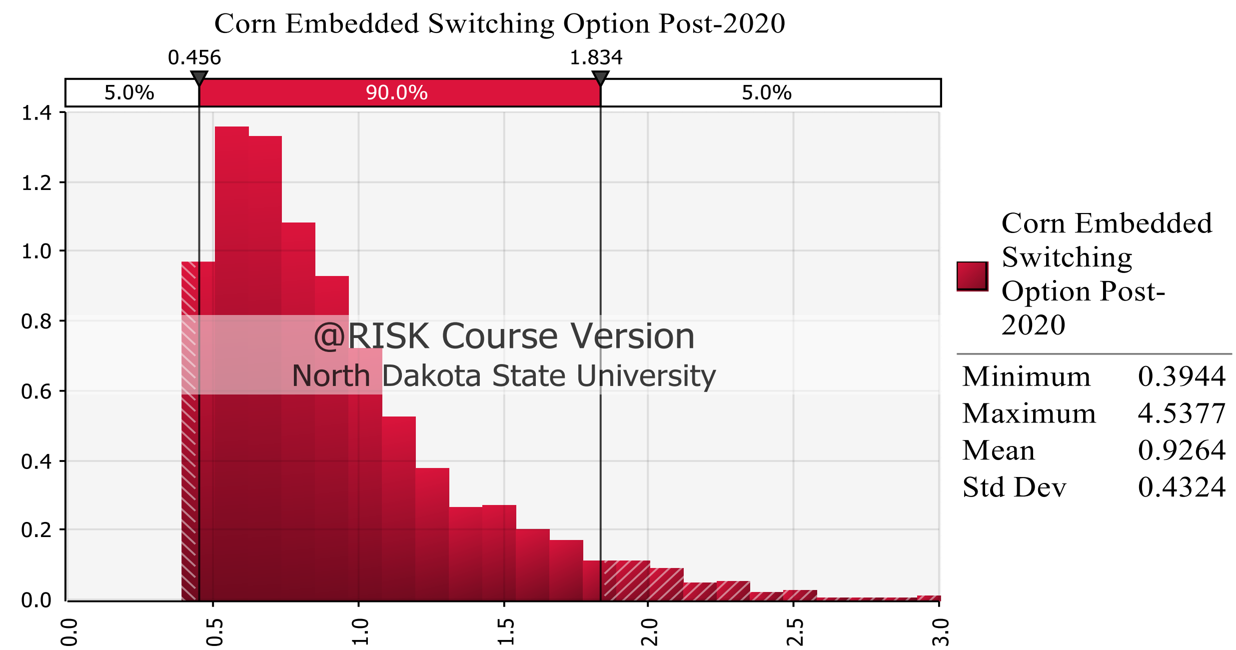

Figure A27. Number of Optional Origins Sensitivity Soybeans Pre-2020

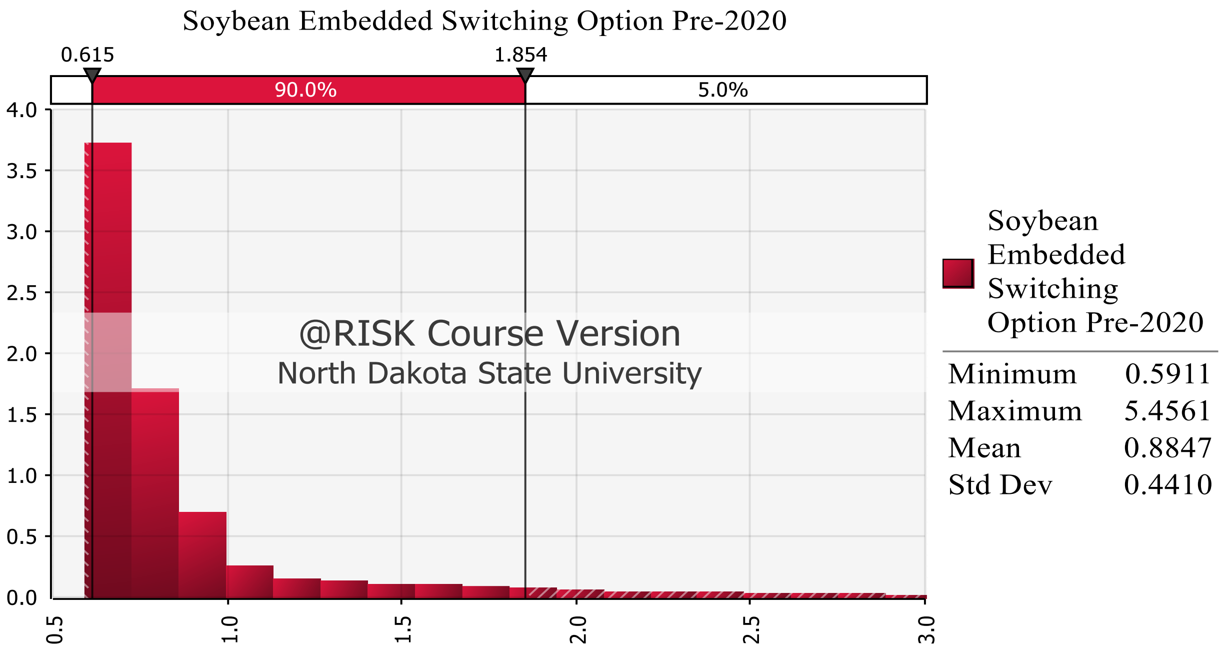

Figure A28. Number of Optional Origins Sensitivity Soybeans Post-2020