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Impacts of U.S. Production-Dependent Ethanol Policy on Agricultural Markets

Jason P.H. Jones, RTI International, jasonjones@rti.org
Bruce A. McCarl, Texas A&M University

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Abstract: U.S. agricultural commodity prices have been volatile in recent years, attributed to many factors, including renewable fuel standard (RFS) mandates. While the RFS is legislatively able to be altered, the mandate largely required the same volume of corn for ethanol in the 2012 drought year as it would have if 2012 were a normal production year. This contributed to a surge in corn prices, having significant economic ramifications throughout the agricultural industry. An important question that arose from these events was if this variability was avoidable with a RFS relaxation policy? In this work, the economic effects of a policy that relaxes ethanol mandates in cases of major corn production shortfalls is investigated to determine the market relationships between RFS policy and commodity markets. This is done in a three step process. First the historical incidence of shortfalls is addressed by developing a stationary probability distribution of total and regional production using econometric procedures. Second, the short-run economic impact of RFS relaxation alternatives is investigated using an optimization modeling framework where crop mix and livestock breeding herds are held fixed. Third, the long-run implications of RFS relaxation are investigated by incorporating a stochastic optimization framework of ag-producer decisions with recourse. When a shortfall driven relaxation policy is in place, crop mix/livestock breeding decisions are able to adjust.

The results show RFS relaxation has a significant impact on reducing price spikes and livestock production impacts due to reduced feeding costs when shortfalls occur. Although an ethanol waiver benefits consumers through decreased commodity prices, the reduction in producer welfare was found to be larger, resulting in an overall negative agricultural sector welfare impact. In the long-run, the RFS relaxation mitigates price spikes during production shortfall years but also stimulates a producer response of decreasing corn acreage due to lower expected prices. This caused corn prices in non-shortfall years to increase, resulting in a negligible impact on the average long-run corn prices, while reducing commodity price variability. The model findings demonstrated that risk reduction implications could exist from a production-dependent conventional ethanol waiver, with limited long-run changes to future expected prices.

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1. Introduction

Renewable fuel standards in the United States began in 2005 with the passing of the Energy Policy Act by the U.S. Congress. This legislation mandated the blending of 7.5 billion gallons of renewable fuel into gasoline by 2012 (U.S. Congress 2005) with the standard referred to as RFS1. In 2006 this amounted to a total requirement of 4 billion gallons, at that time met almost entirely with corn ethanol. RFS1 mandated the percentage of ethanol in gasoline to steadily increase until 2012. Subsequently, this was amended by the Energy Independence and Security Act of 2007, which extended the ethanol target to 2022 plus expanded the required volume. The revised renewable fuel standard (called RFS2) increased the blending amount, including new requirements and ending with a 36 billion gallon obligation by 2022 (U.S. Congress 2007). The RFS2 mandates include specific targets for feedstock based ethanol, advanced biofuels, and biodiesel. The use of biofuel mandates is rapidly becoming a worldwide phenomenon, with world ethanol production increasing from 16.9 to 72 billion liters, and biodiesel production increasing from 0.8 to 14.7 billion liters from 2000-2009 (Sorda, Banse, and Kemfert 2010). This international adoption amplifies the importance of policy implications on global food markets.

Renewable fuel mandates in the U.S. have limited flexibility considering their fulfillment depends on a highly variable supply of agricultural products. While the RFS2 mandates that renewable fuel blending requirements are to strictly increase until 2022, agricultural production experiences substantial variability (Congress 2007). Recently, both the Texas drought of 2011 and the U.S. Corn Belt drought of 2012 have caused commodity prices to reach record highs, while at the same time lowering the U.S. national grain stocks. During 2011, Texas, the third largest agricultural producer in the US, experienced the hottest growing conditions in 116 years of observational data and extremely dry conditions with resultant impacts on agricultural production (Hoerling et al. 2013). The 2012 Corn Belt drought greatly reduced total production, decreasing national production 13% from the previous year, sending corn price to a record high of \$7.63/bu in August 2012 from a level of \$6.88/bu in August 2011, and lowering national grain reserves. This occurred during a year where much of the crop land in the U.S. was dedicated to corn production. Researchers from both the U.S. and Great Britain have found that these extreme heat events have become twenty times more likely to occur relative to other La Niña years due to the effects of climate change (Rupp et al. 2012). An unchanging conventional ethanol mandate in the face of such variability may not be desirable.

1.1. Effects of RFS2 Mandates and Agriculture

The effects of the RFS2 required volumes (hereafter called mandates) on agriculture are multidimensional. First of all, the conventional biofuels portion of the mandate to date has largely been met using corn ethanol, where about 40% (nearly 5 billion bushels) of the U.S. corn crop is used for ethanol production, as depicted in figure 1. The variability of corn available (fluctuating primarily with the yield in that growing year) has recently had minimal impact on the amount of corn that goes into ethanol or food/seed/industrial uses, whereas livestock feed appears to have experienced the greatest annual fluctuations.

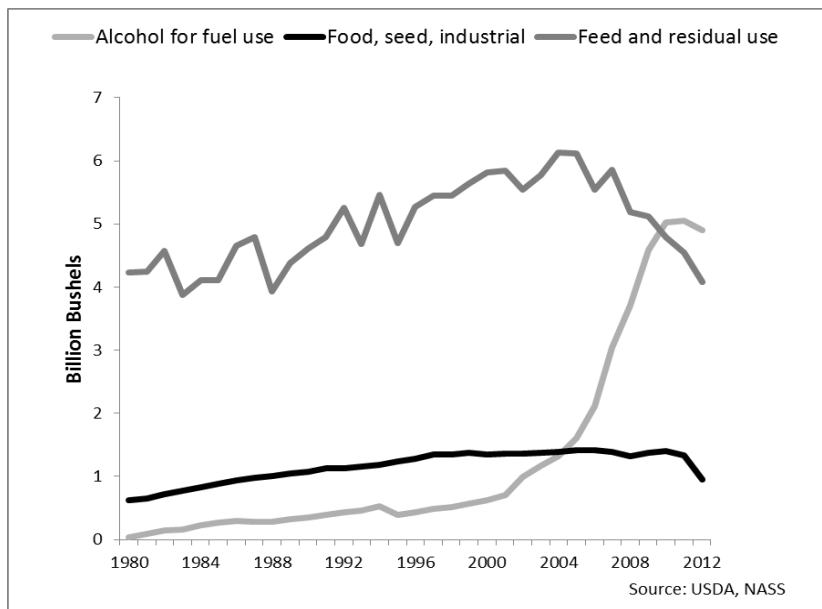


Figure 1. Corn use in the US, 1980-2012

Ethanol manufacturing has recently become the largest end user of U.S. grown corn. Consequently, corn production has increased over 30% since the mandates were implemented with Carter, Rausser, and Smith (2012) finding that corn prices were 30% higher as opposed to the case where ethanol remained at 2005 levels. Also, livestock feeding has become more expensive (Elobeid et al. 2006) and distillers dried grains by-product, an ethanol production byproduct has become a major feedstuff (Taheripour et al. 2010; Hertel, Tyner, and Birur 2010). Anderson, Anderson and Sawyer (2008) argue the situation may alter regional comparative advantage moving livestock production closer to distiller's grains, which are produced in corn producing regions. A number of other developments are occurring including environmental impacts, spillover effects, alterations in infrastructure needs, and stresses on other resources (Suttles et al. 2014; Hertel, Tyner, and Birur 2010; Sorda, Banse, and Kemfert 2010; Golub et al. 2010). Furthermore, although the mandates have been put into law, the future of U.S. renewable fuel standards remains unknown. This is due to issues such as the ethanol blending wall, pertaining to usage in conventional motor vehicles and the lack of current availability of a large scale, cost effective, viable, cellulosic ethanol processing technology. Recently, almost all of the required cellulosic ethanol has been waived due to the limited supply, in addition to reduction in future cellulosic requirements relative to the original RFS2.

1.2. Agriculture and Uncertainty

An important facet of the relationship between current biofuel mandates and agricultural market variability is uncertainty. Agricultural production is heavily influenced by weather and other stochastic pressures that are unknown when the decision to allocate agricultural land uses takes place. Similarly to primary agricultural producers, the renewable fuel sector also make decisions based on anticipated production levels and expected future commodity prices. On the other hand, renewable fuel policy is set *a priori*, for the most part unconditional on agricultural production and annual fluctuations in crop availability. As a consequence, prices can rise quite high, for example during the 2012 drought, reaching

above \$7/bu, whereas pre-mandates they were about \$2/bu. A waiver for corn ethanol production is a legally available option; however a production dependent option has not yet been exercised, even in the instance of the 2012 drought. An issue examined here will involve the effect of making renewable fuel mandates conditional on total production, perhaps reducing market volatility.

There currently exists a policy mechanism to accommodate minor production fluctuations, the renewable identification number (RIN) credit system. Research has found this program does influence commodity prices during production deficient years, with corn price spikes found to be reduced \$0.91 per bushel under the system (Babcock 2012a). However, the impact on corn prices in a drought year will continue to be a factor unless a waiver is implemented (Babcock 2012b); due to limits and rigidities in the tradable permit system for intra-year trading and consecutive production shortfall events. These studies also provide a detailed description of the permit system, outlining its structure.

In regards to production dependent policy, current legislation indicates that the Environmental Protection Agency (EPA) can only issue a waiver on conventional ethanol if 'economic harm' is evident in the market (Tyner 2013), an outcome not explicitly defined by the agency. The primary reason why a waiver was avoided during the 2012 drought was that the EPA assumed its use would cause unwanted agricultural market and ethanol blender actions (Tyner 2013).

1.3. Research Objectives

The current study investigates the long-run economic impacts of relaxing the RFS2 mandates in the face of production shortfalls. Unlike conducted in previous ethanol waiver analyses, market participant response to such a policy will be incorporated in the framework. It is important to investigate if long-run adjustments to such a policy have the potential to provide a less volatile market, through long-term adjustments of land use. The long-term economic consequence of such actions will be evaluated, in regard to commodity price impacts, and the subsequent welfare changes among various sectors. This research contributes to this body of literature by providing the necessary insight into the expected responsive actions of producers given an explicit ethanol waiver policy.

This work is carried out in a two stage process. The first step involves the development of a stationary probability distribution for total US agricultural production and the subsequent identification of production shortfalls occurrence. This is conducted using time series regression analysis on state and crop specific historical yields, focusing on the difference between expected and experienced production levels. Following, a stationary yield probability distribution for total production is formed and representations of production shortfalls, in addition to their respective probabilities are identified.

Second, the long-run implication of adopting a formal policy of mandate relaxation under agricultural production shortfalls will be investigated using a decision with recourse variation of the Forest and Agriculture Sector Optimization Model (FASOM) of the US agricultural sector. This dynamic optimization model provides a U.S. state-level scale of analysis, required to fully incorporate the regional characteristics of drought, while allowing for feedback effects through the biofuel, crop, and livestock sectors. The model advancement used in the current analysis follows the work in Lambert et al. (1995) and Butt and McCarl (2005) by integrating a stochastic production component, allowing for the

incorporation of state and crop specific yield variability profiles reflective of 63 years, from 1950-2012. These long-run impacts will be compared to a short-run situation where producer responses to the implementation of a waiver are limited.

As mentioned, the implementation of an ethanol mandate waiver is permitted by EPA legislation; however its implementation with respect to incidence and magnitude of production shortfalls remains uncertain. The certainty inherent in the policy under investigation will allow producers to adopt long-run adaptation strategies with consideration of the production dependent biofuel scheme. Thus, assuming rational producer expectations, producer decisions will incorporate this policy knowledge when determining expected future prices (i.e. reduced corn price spikes during years of extreme drought) brought on by the altered policy before the planting period. This analysis of the long-run economic consequence of an explicit waiver policy will be important in determining the implications of the uncertainty inherent in current ethanol waiver policy.

2. Theory and Methods

2.1. Regression Analysis

Crop yields are difficult to forecast, incorporating both spatial and temporal variability, dominated by rainfall occurrence alongside other climatic and weather factors (Potgieter, Hammer, and Butler 2002). In addition, there are an array of technological, economic, environmental, policy, and other factors that impact crop yields. When considering the estimation of a simple time trend with respect to yield, the associated factors must be categorized. The influences on yield that we assume will change with time will be considered 'technical change' for this analysis. On the other hand, such influences associated with production variation within a single period, unexplained by changes between years, will be considered residuals or error terms. What is important to how the distributions will be used in the current analysis is that all factors in the 'technical change' category are assumed to be known by farmers, given rational expectations. Also, the opposite must hold true of the factors in the residual or error term category. After the trend factors are deduced, market participants cannot predict these impacts on observed yields, most commonly associated with seasonal growing conditions.

A statistical analysis of historical yield deviations is first required to reflect inherent crop production risk in the subsequent economic analyses. Here the probability and magnitude of prior yield occurrences are determined. In addition, the spatial scale, due to that used in the economic model, is required to be at the U.S. state and individual crop species level. In addition, an aggregate distribution is also required to trigger the production dependent ethanol waiver. To develop a total and regional yield joint probability distribution we need to create stationary yield distributions, obtained by the adding the simple linear regression fitted values for a subsequent year to the unexplained errors from the regression. Thus, deviations from the expected yield, in the form of residuals, will be used to represent the production variation as well as their respective geographical severities. This creates the states of nature for the stochastic economic analysis later detailed.

The statistical tool required for the precursor analysis is the linear regression in linear and log form. Previous research investigating yield variability over time has also used regression analysis (Reilly et al. 2003). Using statistical methods, the variability in crop yields over time is examined by factoring in technological change over time. Technological change is essential to this analysis because yields have increased over time due to the effects of crop breeding, increased management, and other factors. This analysis assumes technological change is constant in linear or logarithmic form during the study period (Griliches 1957; Hafner 2003; Tweeten 1998; Dyson 1999), following recent research by Baker et al. (2013). Previous research has also included quadratic equations to explain this relationship, particularly in the cases where fertilizer data is included as an explanatory variable (Cerrato and Blackmer 1990). Regressions were done over the complete 1950-2012 data set, in addition to subsets of; 1975-2012, 1980-2012, and 1990-2012. The subsets were chosen based on prior research findings where decreased productivity improvements have been evident (Havlik et al. 2013; Feng 2012), and the existence of “break points” when using basic linear and log regressions on crop yields over a similar time horizon (Baker et al. 2013).

The regressions are conducted for each crop in each U.S. state, incorporating the spatial correlation inherent in expected crop yields. Equation (I) depicts the simple linear regression formula used to explain yields, y . This formula is used to determine the trend over subsequent crop years, for each crop, in each U.S. state. The residual, denoted as u , incorporates all variation in the yield not explained by the time trend. B_0 and B_1 are the intercept and time trend slope coefficient, respectively.

$$y = B_0 + B_1 Year + u \quad (I)$$

$$\log(y) = B_0 + B_1 \log(Year) + u \quad (II)$$

Equation (II) shows the log-log regression formula also implemented in the analysis, however the fitted and residual values were transformed using exponential functions in order for the statistically estimated yield growth parameters incorporated in the later structural models to reflect real values. Only coefficients above the 90% level of statistical significance were incorporated into the further analyses, however the majority of the agricultural producing states and crop pairs were significant at the 99% level, showing strong statistical evidence of a time trend.

State yield data from the USDA National Agricultural Statistics Service (USDA 2014) database was used for corn, cotton, hay, rice, rye, oats, sorghum, soybeans, sugarcane, silage, sugar beets, potatoes, oranges, grapefruit, and five categories of wheat. Observations were obtained for the 1950-2012 timeframe. The USDA yield data is based on phone surveys with 5,500 to 27,000 participants, and is publically available from the Quick Stats 2.0 database on the USDA NASS website. The functional form ultimately selected for each crop-state pair was chosen based off the highest relative R-squared, specific to each of the time-frame scenarios.

The deviations from expected yield (or residuals) are then converted to exogenous percentage shocks to create stationary yield distributions for the sectorial analyses. In all, nearly 5000 separate yield regressions were required, specific to; crop, U.S. state, functional form, and regression period. The General Algebraic Modeling System (GAMS) software was utilized for automation. Due to the sheer number of regressions, tests for the existence of heteroscedasticity were therefore not conducted. Several studies have found that crop and region specific yield variability has been impacted over time due to climatic factors however the results have been mixed (Isik and Devadoss 2006; Chen, McCarl, and Schimmelpfennig 2004; Reilly et al. 2003; Southworth et al. 2000).

2.2. Production Dependent Renewable Fuel Standard Scenarios

Here, we condition the conventional ethanol waiver policy on total corn production variations. Figure 2 presents the final distribution of national corn production variability developed using the yield distributions calculated previously and normalized 2012 acres. Acreage was normalized to better reflect the production impact of regional yield variation on modern cropping acreages. Over time farmers have migrated crop acreage in response to many economic, agronomic, and climatic factors (Mu, McCarl, and Wein 2013; Lambin and Meyfroidt 2011; Baker et al. 2013; Lambin et al. 2001). According to USDA acreage data, more than 10 million acres have migrated out of corn production in the Southeast U.S. since 1950, primarily in Mississippi, Georgia, Alabama, Tennessee, Arkansas, and North and South Carolina (USDA 2014). In contrast, there have been increases in corn acreage over this timeframe in the northern states, primarily the Dakotas, Nebraska, Minnesota, Wisconsin, Iowa, and Illinois.

It was found to be computationally demanding for the FASOM model to incorporate 63 states of nature, therefore, an empirical distribution was formed that reflected the full data set in 10 production categories with their respective probabilities of occurrence. The most recent year of occurrence was selected as the representative year within each category. The policy trigger is based off of U.S. corn production deviations, although the stochastic component of the model incorporates the deviations in all crop yields. Corn production shortfall years are assumed to be the dark grey (shortfall) and black (extreme shortfall) boxes in Figure 2. These years, represented by the 1993 and 1995 growing seasons (although also representing the dust bowl years of the 1950's, 1964, and 1974), have a probability of 6 years out of 63. In the case of the 'extreme' shortfall case, 2012 is the representative (also representing 1988 and 1983), thus occurring 3 years out of 63.

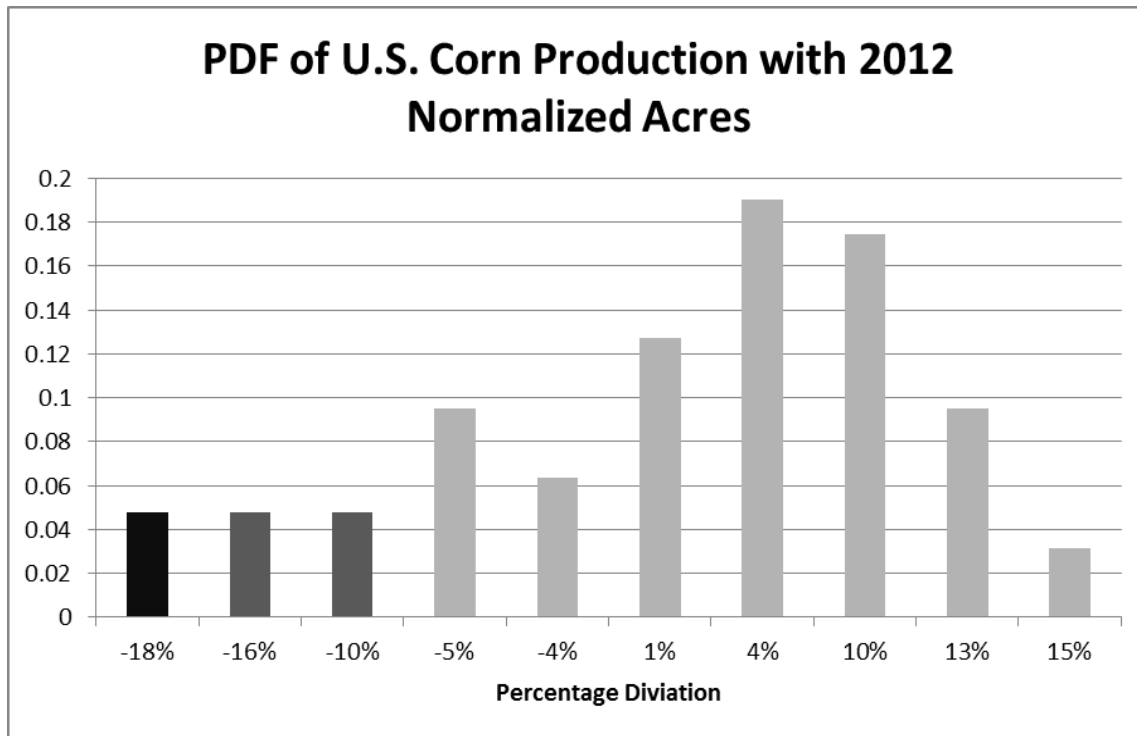


Figure 2. Discreet representation of the PDF of 1950-2012 U.S. corn production, depicting short-fall triggers

Twelve RFS mandate reduction scenarios were incorporated, ranging from no reduction to up to 50%. Table 1 outlines the mandate reduction scenarios, stating the total required volume of conventional ethanol in either a moderate or extreme shortfall scenario. In a non-shortfall experience (54 out of 63 cases, or 85% of the time), no waiver is implemented, and the 15 billion gallon requirement from the original RFS2 is upheld. In the scenarios presented in Table 1, the mandate reduction amounts can vary across either the 'moderate' and/or 'extreme' shortfall circumstances. Scenarios 2-6 have smaller reductions (1-2 billion gallons) while cases 7-12 are larger (3-7.5 billion gallons).

Table 1. Production-Dependent Conventional Renewable Fuel Standard Policy Scenarios

Scenario	Conventional Ethanol Mandate in Billion Gallons	
	Moderate Shortfall	Extreme Shortfall
Baseline	15	15
2	15	14
3	15	13
4	14	14
5	14	13
6	13	13
7	15	12
8	15	10
9	15	7.5
10	12	12
11	12	10
12	12	7.5

Although market participants are unaware which specific yield state will occur, the distribution is known with certainty. Given the implicit model assumption of rational expectations (Muth 1961), participants act accordingly based on this knowledge. Outcomes are then calculated across all states of nature and policy scenarios. Multiple scenarios concerning RFS policy and yield distributions are constructed for comparison and robustness. Given the long-run characteristics of the current analysis, this enables an exploration into the potential shifts in cropping patterns within and across regions in response to changing RFS waiver policy.

Agricultural Sector Model

The primary tool for the current analysis will be the Forest and Agricultural Sector Optimization Model (FASOM) mathematical programming representation of the agriculture and forestry sectors in the U.S. (Adams et al. 2005; Beach and McCarl 2010). The complete model framework maximizes a function that reflects total welfare as a result of activities in the agricultural and forestry sector. The FASOM model has been recently employed to determine the impacts of the latest biofuel mandates on Agriculture and Forestry, particularly concerning policy impacts on GHG emissions (Beach and McCarl 2010). FASOM is modular in nature, including such elements as land use, crop and livestock production, forestry production, commodity processing, greenhouse gas emission considerations, and biofuels.

FASOM includes over 100 commodity types, 40 crops, 25 livestock units, and over 50 processed goods. Factor markets concerning; irrigation, fertilizer, and labor are also included. Product markets are incorporated using production/supply, consumption/demand, and international trade. Specifically, production is dependent on the endogenous input and output factors, various production technologies,

as well as exogenous yield estimates, based on previous literature or statistical methods applied to historical data.

The constraints of this maximization procedure are grounded in basic economic theory, whereas supply (determined by technological assumptions, available land, inputs, import markets, and alternative production options for the producer) and demand (determined by domestic demand, the intermediate product market, and export demand) determine the resulting prices. The model prices are extracted from the program results as the marginal value of an additional unit of supply. The model also allows for a certain degree of substitutability in demand for agricultural products, for instance, the closeness of beet sugar and cane sugar. The model constraints ensure a supply-demand balance holds for regional product supply, demand, processed commodities, trade, feeding, livestock markets, and transportation between U.S. states. Non-linearities in demand are depicted in the model using separable programming. Within the supply balance, total land constraints also exist for each U.S. state, treating production possibilities as heterogeneous across the state and sub-state regional scale.

The FASOM model has not been employed to investigate the economic impacts of biofuel mandates in the event of an unexpected negative supply shock. This exogenous shock, combined with the additional upward pressure on corn prices from ethanol mandates, is expected to severely strain the supply of corn, causing market impacts throughout the U.S. agricultural sector.

Long Run vs. Short Run Agricultural Sector Model Implementation

The difference between the short- and long-run models presented is focused on producer responsiveness to policy. In the short-run, it is assumed that producers have already committed to planting decisions, and such decisions did not anticipate a biofuel waiver. The short-run framework will be used to evaluate a waiver policy that does not have explicit conditions for implementation, as is currently the case. The market impact of the drought conditions will be evaluated with various waiver types.

On the other hand, the long-run model can be used to evaluate a waiver policy where the public is aware of the specific conditions required for its implementation. Although agricultural production is stochastic, it is assumed producers have knowledge of historical yields, and therefore can imply the expected changes such a policy would have on prices, thus altering their behavior. Therefore, market impacts of drought can again be evaluated in all yield circumstances given the waiver policy.

Short Run Agricultural Sector Model Implementation

It is hypothesized that consumers of agricultural products will be made worse off in the short-run due to the inflated prices caused primarily by corn but also indirectly through a reduced supply of other agricultural commodities. In particular, ethanol policy has incentivized an increase in the total acres of corn, reducing the available acreage of other crops, thus having impacts on the production of all agricultural commodities. Since the drought is unexpected, the acreage is unable to respond to the negative supply shock, thus causing upwards pressure on commodity prices. In this short-run analysis

we assume that acreage of a crop is fixed, for the policy waiver and drought occurrence is assumed to be realized after producers have planted.

Commodity prices, most notably corn, are predicted to rise due to the drought and the corn dedicated for use in ethanol production. Ranchers are expected to decrease their herd size and feeding due to high feed costs, causing mixed effects on beef prices. This will hurt beef producers while having a positive impact on consumers; however these impacts are highly dependent on the relative supply and demand elasticities. These effects are likely to be relatively large in the short-run compared to the long-run analysis due to the inherent inflexibilities in the supply chain. Based on rational expectation theory, the analysis assumes that producers did not expect an ethanol waiver.

The first procedure implemented for the following analysis, as described previously, involves forming the 2015 yield distribution under an event of the magnitude of that which happened in 2012. This is done by extrapolating the yield regression analysis on state-specific crop yields to 2015 and applying the 2012 residuals. In turn, those yields are incorporated into the partial equilibrium framework, FASOM.

Stochastic Long-Run Economic Modelling Framework

Modification to the deterministic partial equilibrium framework of FASOM is required to incorporate market outcomes under alternative states of nature. This research wishes to integrate stochastic yield states into the model. The objectives for this modified model are to allow certain model participants the ability to respond to stochastic outcomes, while restricting the ability of others. In this circumstance, it is assumed that crop production decisions are based on yield distributions and demand curves, without realizing actual yields or prices. Thus, producers choose to maximize expected revenue based on expectations. On the other hand, consumers, livestock feeders, and processors are assumed to be able to alter their production and consumption decisions based only on the realized yield outcomes. This implies yield risk must also be incorporated into the markets for intermediate goods, such as the corn available for ethanol processing. Therefore, the ethanol mandate needs to be incorporated in such a way that its implementation can be conditional on states of nature, while only the distribution of such nature states are known *a priori*. Although acreage was fixed for the short-run analysis, partial decision with recourse was incorporated into the short-run analysis through a number of decision variables. Farmer decisions that were allowed to depend on realized yields were limited to processing, livestock feeding, and trading patterns.

Stochastic programming with recourse was originally portrayed and generalized within the management sciences (Dantzig 1955; Cocks 1968). The agricultural application of this framework has developed considerably since this time (Rae 1971, 448-460; Lambert and McCarl 1985, 846-852), generally finding that results differ relative to deterministic models using mean values. The framework used in the current analyses follows research from the agricultural economics literature (Lambert et al. 1995), incorporating adaptive behavior and derived demands in the agricultural setting.

The model is as follows:

Max

$$\begin{aligned} \text{Total surplus} &= E(\int p(q) dq - g'y) - c'x \\ &= \sum_{s=1}^N (\theta_s \int p(q_s) dq_s - g'y_s) - c'x \end{aligned} \quad (IIIa)$$

Subject to:

$$q_s + Hy_s - N_s x \leq 0 \text{ for all } s, [\pi_{1s}] \quad (IIIb)$$

$$My_s \leq e \text{ for all } s, [\pi_{2s}] \quad (IIIc)$$

$$Dx \leq b \quad [\pi_{3s}] \quad (IIId)$$

$$q_s, y_s, x \geq 0 \quad (IIIe)$$

where θ_s is the probability of each state of nature occurring s , $p(q_s)$ is the inverse demand curve where q_s is a vector of final goods, g is a vector of processing costs, H a matrix of production activity, y_s is the state dependent vector of processing using primary production, consuming goods when $H > 0$ and producing when $H < 0$. M is the matrix of resource usage of processing, where the processing resource endowments are defined by e . Primary agricultural production levels are denoted deterministically as x , given resources b , and the resource usage matrix D . The stochastic effect on the model is represented through N_s , the matrix of all yields under each state of nature. The shadow prices from the constraints are depicted as π_{1s} , π_{2s} , and π_{3s} . In all, producer and consumer surplus is maximized given each state of nature (IIIa) subject to supply balance constraints for each state (IIIb), processing resource endowment given each states production (IIIc), primary agricultural production resource endowments (IIId), and non-negativity constraints.

In addition to the general structure of the Lambert et al. model depicted above, a further constraint is required to incorporate biofuel policy. Model bounds depicting biofuel processing were included on the relevant elements of the y_s vector to force a minimum amount of processing of corn into ethanol with the per unit yield EY to meet the RFS requirements. Since the biofuel constraints in the current analysis are state dependent, the right hand side values of these constraints also is dependent on s . This constraint is depicted as follows:

$$EY y_s \geq m_s \quad [\pi_{4s}] \quad (III f)$$

Equation (III f) presents the additional constraint where final production is set to be greater than a certain mandate, denoted m_s , and π_{4s} is the shadow price of the RFS constraint. This analysis assumes that the RFS upper bound of 15 billion gallons on corn ethanol does not constrain production. Below, p_s is the state-specific demand curve, defined as $p_s = a - Bq_s$, where a is the intercept and B is the slope coefficient. The first order conditions of the Lagrangian depicted from equations (IIIa-f) with respect to final output q_s when $q_s > 0$ is as follows:

$$\frac{\partial L}{\partial q_s} = \theta_s [a - Bq_s] - \pi_{1s} \leq 0 \quad (IV)$$

This simplifies to:

$$\pi_{1s} = \theta_s [a - Bq_s] \quad (V)$$

The first order condition with respect to state dependent processing levels y_s from the Lagrangian is:

$$\frac{\partial L}{\partial y_s} = -\theta_s g + H\pi_{1s} - M'\pi_{2s} - EY \pi_{4s} \leq 0 \quad (VI)$$

If we look at the ethanol processing activity only, assuming it is zero, the expression becomes an equality, plus adopting the assumption that the corn use is 1 unit where EY is the ethanol yield from processing, this becomes:

$$-\theta_s g + \pi_{1s} - M'\pi_{2s} - EY \pi_{4s} = 0 \quad (VIIa)$$

or,

$$\pi_{1s} = \theta_s g + M'\pi_{2s} + EY \pi_{4s} \quad (VIIb)$$

Therefore, the commodity price also equals the cost of producing ethanol (g) plus the cost of the resources used, plus the cost of mandate times the ethanol yield.

In turn simultaneously solving the equations (V) and (VII), we see the price under the sth state of nature we get:

$$[a - Bq_s] = g + M'\pi_{2s}/\theta_s + EY \pi_{4s}/\theta_s \quad (VIII)$$

Equation (VIII) shows that the equilibrium price and associated quantity from the processing market includes the mandate requirement, as would be expected. The first order condition with respect to primary agricultural crop production levels x from the Lagrangian is:

$$\frac{\partial L}{\partial x} = -c + \sum_s N_s \pi_{1s} - D'\pi_3 \leq 0 \quad (IVa)$$

From (V):

$$\frac{\partial L}{\partial x} = -c + \sum_s \theta_s N_s [a - Bq_s] - D'\pi_3 \leq 0 \quad (IVb)$$

Substituting in equation (VIII), this equals:

$$\frac{\partial L}{\partial x} = -c + \sum_s \theta_s N_s (g + M'\pi_{2s}/\theta_s + EY \pi_{4s}/\theta_s) - D'\pi_3 \leq 0 \quad (IVc)$$

From equation (IVc), we can see that the production decision responds to the expected demand curve price, also involving the state specific cost of the biofuel mandate, represented by π_{4s} . Assuming that the mandate m_s is binding, thus $\pi_{4s} > 0$, increasing m_s would impact the level of crop production x , irrespective of the state of nature. Therefore, if yield-outcome specific mandates were introduced into the model, the decisions made prior to yield realization would be affected.

The stochastic programming framework originally presented by Lambert et al., with modification presents a formulation that allows explicit outcomes for each state of nature to be depicted, enabling the yield distribution data to be incorporated in its raw form. In addition, risk for such intermediate commodities as corn can be determined since processing, ethanol constraints, and consumption both depend on the state of nature.

Corn Production Deviations

Corn production variability from year-to-year is based on factors including acreage, technological change, and growing conditions. Unlike in the short-run analysis that described a 2012 year-specific percentage shock to yields, total corn production deviation calculations are required to rank each possible state of nature. This is required in regard to the severity of the drought's impact on the total U.S. corn production. This ranking will allow for the construction of an empirical distribution of possible yield states as to identify drought and severe drought occurrences, thus enabling for the stochastic analysis.

Initially, the percentage deviation from each year's expected yield is calculated using the difference between expected production levels, and the actual yield data. This analysis required the use of the fitted yield values from the regressions previously described and the actual yield data from NASS (USDA 2014). Since our goal is to identify the most severe periods of decreased production, these state specific yield variations were multiplied by each states harvested acres. These calculations provided an estimate of the variation in production for each crop in each state, subsequently summed to attain a national production variation estimate. In order to create our drought scenarios, all subsequent growing years were ranked by national corn in order to construct a distribution. In order to ensure this measure was comparable across years with varying harvested acres, the variation in production was divided by the expected production in each year. This procedure generated a distribution in terms of percentage deviation from expected production for each year.

As expected, the probability density function of this distribution exhibited a long left-side tail, exhibiting the probability, however low, of severe negative production shocks. This can be seen in Figure 3, depicting the US corn production deviation probability distribution function using the 1950-2012 regression data interval. The figure shows the corn crop has experienced production variation up to 25% less than expected and upwards of 17% above expected during the 1950-2012 time period.

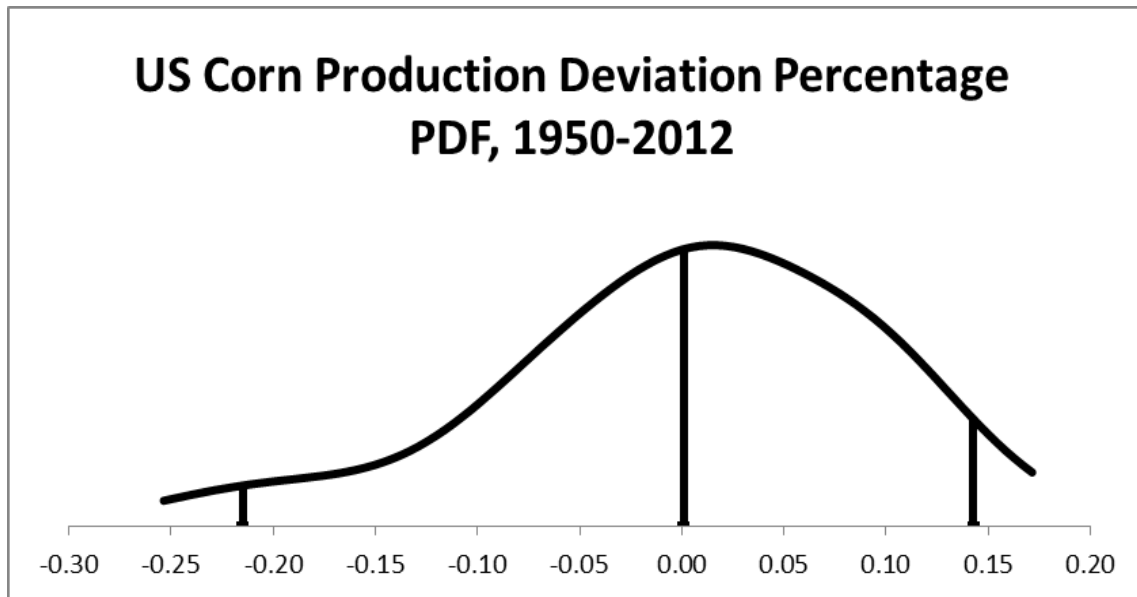


Figure 3. US corn production deviation probability distribution function, 1950-2012

Due to significant regional crop shifts over the regression period, production variation was normalized to reflect a 2012 acreage distribution across all states. Thus, for each state, harvested acres at 2012 levels were multiplied by yields in each respective period, then by one plus the percentage deviation specific to that scenarios growing year, as calculated previously. This produces a metric that reflects the impact of previously experienced growing conditions giving recent crop allocations. The normalized corn production percentage deviations from trend line values can be seen in Figure 4, depicting the percentage deviation in corn production given an acreage distribution that reflects 2012. Using this normalized acreage metric, the 2012 drought is seen as the second most extreme, only less than 1988, corn production shortfall since 1950.

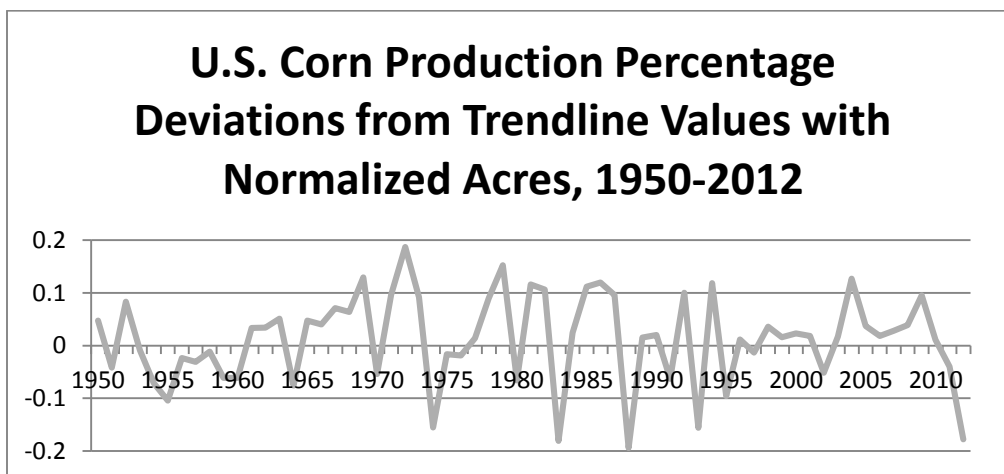


Figure 4. Corn production variation using normalized 2012 acres, 1950-2012

3. Results

This section presents the results for both the short- and long-run analyses. Equilibrium prices are determined for both scenarios. In our short-run scenario, where producer's acreage decisions are held constant, acreage results do not change. The long-run results are displayed across our crop production scenarios represented by the PDF above in Figure 2.

3.1. Short-run Scenario Results

Table 2 shows the corn and soybean price results. In the absence of drought, given the various RFS scenarios, the base case projected corn and soybean prices for 2015 to range between \$5.91-\$6.07 and \$12.29-\$12.38 per bushel, respectively. Due to the similarities in the results among regression periods, only the 1950-2012 tables are presented. Given RFS2 mandates are fully in place, and 15 billion gallons of corn ethanol is being produced, the 2012-like production shortfall caused corn prices to nearly double, increasing between 91%-95%, to \$11.66-\$11.82 a bushel. This increase in corn price is higher than found in a previous study when a negative supply shock similar to the 1988 drought under an ethanol mandate scenario saw corn prices increase 43.8% (Tokgoz et al. 2008). On the other hand, corn prices increase only 6%-12% when relaxing the RFS mandate in the same drought situation to \$6.36-\$6.65. This shows that a RFS waiver is expected to have significant short-run price consequences, reducing the severity of the positive spike in corn price.

The impact of the drought on soybean prices was found to be relatively small. In addition, relaxing the corn ethanol mandates actually had minor positive impacts on soybean prices. This is most likely because the biodiesel mandates were not altered.

Something of interest is the lack of price difference given the three RFS scenarios. This was a significant result, particularly in the case of scenario two, where over four billion gallons of cellulosic ethanol was produced to satisfy the original RFS2 requirement for 2015. Since the results show that there is no real effect of the cellulosic ethanol scenarios, we will not discuss those further.

Table 2. Corn and Soybean Price Results for 2015 under a 2012-like Supply Reduction

			Production Short-fall Scenarios			
			Relaxed			
	RFS Cellulosic Scenario	Base	Full RFS and Short-fall	%Δ from Base	RFS and Short-fall	%Δ from Base
Corn Price /bu	Final Rule	\$5.92	\$11.66	97%	\$6.62	12%
	Full Cellulosic	\$6.01	\$11.66	94%	\$6.46	8%
	No Cellulosic	\$5.98	\$11.82	98%	\$6.36	6%
Soybean Price /bu	Final Rule	\$12.17	\$12.50	3%	\$13.93	14%
	Full Cellulosic	\$12.26	\$12.70	4%	\$14.10	15%
	No Cellulosic	\$12.24	\$12.61	3%	\$14.19	16%

Notes: Base scenario depicts the situation in which no drought occurred. Prices in 2014 US Dollars.

The basic results across the RFS cellulosic relaxation scenarios is that the production shortfall coupled with the RFS leads to a substantial rise in prices with them raising from \$5.92-\$6.01 per bushel to \$11.46-\$11.82. This found that given a drought occurrence, current RFS standards would increase corn prices by almost \$6, or a near doubling, whereas relaxing the corn ethanol mandates by 50% dampens this price spike to \$6.36-\$6.72, less than a one dollar increase.

Table 3. Production and Price Indices Following 2015 Drought

Commodity Index	Price Index		Production Index	
	Full RFS	RFS Relaxed	Full RFS	RFS Relaxed
Crop	134.7	109.6	85.9	86.7
Livestock	133.4	132.0	91.0	97.9
Meat	119.6	106.1	87.2	93.2

Notes: Index values are relative to the baseline expected yield scenario without short-fall at 100.

The weighted price index for meats is also depicted in Table 3, denoting a near 20% increase when corn ethanol mandates remain in place. This is relative to a 5-6% increase when such RFS standards are relaxed.

Production across all commodity categories decreases relative to the drought free situation. Crop production declines 13-14%, with very little difference regarding the status of the corn ethanol mandate due to the model lock-in. Livestock production declines 8.5-9.1% given adjustments made in response to higher feeding costs. Given a relaxed RFS mandate and the subsequent less expensive feed, this decline is smaller, at 2.1-2.3%. Lastly, meat production decreases 12-13% given RFS mandates and 6.4-6.8% when such mandates are relaxed. This is a difference of nearly half between the policy alternatives.

3.2. Crop Ethanol Mandate Sensitivity

The results depicted so far display select cases for ethanol mandate waivers, while in practice; it is valuable to know the marginal impacts of such a reduction. The data presented in Table 4 shows the resulting corn price of marginally decreasing the mandate for the 2015 drought simulation plus under base yields. Under the base yields we see corn prices show little response to changes in the mandate after decreasing the mandates by only a few billion gallons. This result shows that crop ethanol mandates, given the 2015 yield projections, do not positively impact corn price until after 13 billion gallons given this production situation. A meta-analysis of previous biofuel and corn price studies given unexpected short-run implementation of ethanol waivers where each additional billion gallons of ethanol is associated with a 5 to 10 percent increase in corn prices on average (Condon, Klemick, and Wolverton 2015). This was the case in our model findings, until a lower bound corn price is reached; a price influenced by other factors not directly associated with biofuel mandates.

Table 4. 2015 Corn Price in dollars/bu Sensitivity to Crop Ethanol Mandates Given 2012 Drought

Crop Ethanol Mandate (billion gallons)	Normal Yields	2012 Drought Regression Scenario
15	\$5.92	\$11.65
14	\$5.69	\$10.83
13	\$5.65	\$10.30
12	\$5.65	\$9.76
11	\$5.65	\$9.33
10	\$5.65	\$8.69
9	\$5.65	\$8.21
8	\$5.65	\$7.84
7	\$5.65	\$7.53
Relaxed (0)	\$5.65	\$6.61

Note: Prices shown in 2014 US Dollars.

However, the situation is dramatically different under the 2012 imposed drought yields, where we see the mandate has large impacts on corn price. The table above shows that given a 1 billion gallon decrease in crop ethanol mandates in the drought situation, corn prices would decrease from their \$11.65, on average 50 cents, however, this effect is marginally decreasing as the size of the waiver increases, as depicted in Figure 5.

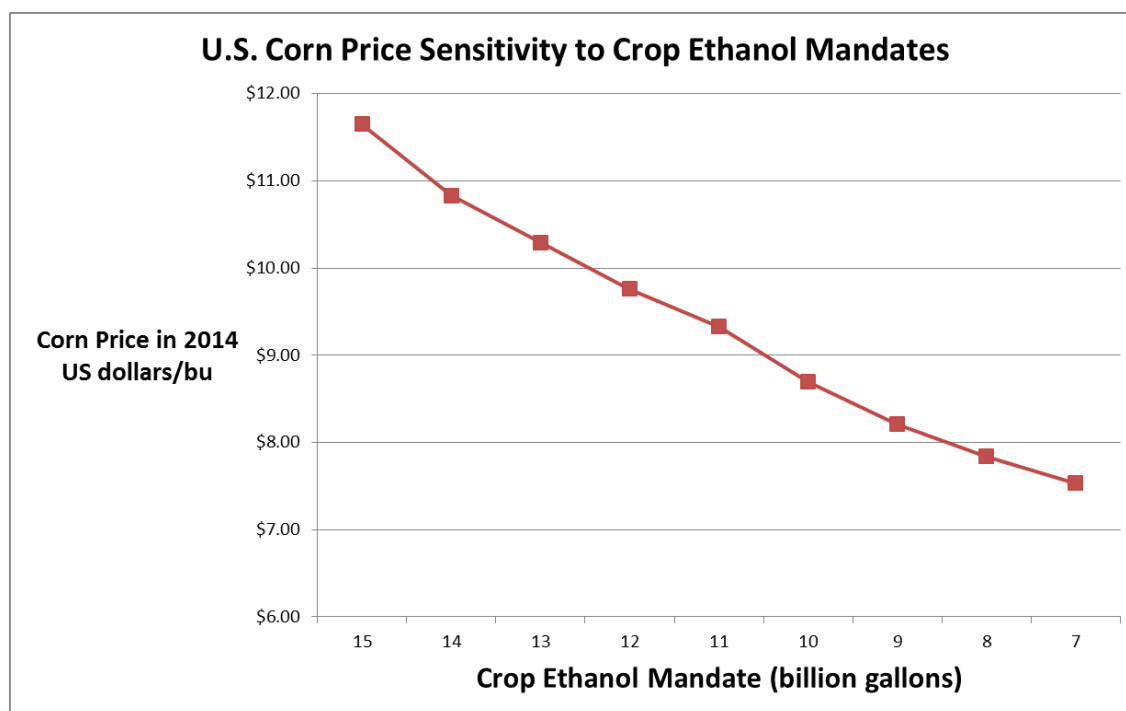


Figure 5. 2015 U.S. corn price given 2012 drought sensitivity to marginal decreases in crop ethanol mandates

Imposing policy that relaxes the biofuel mandate causes consumer surplus to be higher than in the case RFS remained, due a relief to the positive pressures on commodity prices. In this case, short-run consumer welfare would be \$29.2 billion USD higher given the relaxation of conventional biofuels during the drought.

The alternative side of the welfare analysis is the welfare impacts on producers. Since drought occurrence combined with tight ethanol mandates cause agricultural output prices to increase, it was initially expected that relaxing such mandates during drought years would negatively impact producers, because they would now face lower market prices for outputs. Producer welfare changes were also calculated from the initial non-drought, base level, with respect to a 2012-like drought given both full RFS and a relaxed situation. In both policy situations, the drought's impact on price for most regions increases producer income, thus the price rise is exceeding the negative impact on production through reduced yields.

3.3. Long-run Scenario Results

Generally, the corn price was found to increase given waivers during years in which no production shortfall was experienced (Table 5). This can be seen by the representative states of nature 2002, 2004, 2008, 2009, 2010, and 2011, due to decreasing production levels. These price increases are relatively small; however these years represent the portions of the production distribution with the highest probability. The reasons for this increase involve reductions outlined in the acreage results section below. On the other hand, during the representative year that depicts the largest production

shortfall, 2012, corn price experiences a relatively large decrease in price under the mandate relaxations. The variance of the price distribution however does show a considerable change, represented by the coefficient of variation, with larger waivers exhibiting less corn price variance across all yield possibilities.

Table 5. U.S. Corn Price by Representative State of Nature Given the Smaller Waiver Scenarios, 1-6

State of Nature	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)					
	Base	2	3	4	5	6
son1979	3.13	3.13	3.14	3.14	3.14	3.14
son1993 ¹	7.86	7.89	8.09	7.33	7.59	7.04
son1995 ¹	6.40	6.54	6.74	5.97	6.04	5.55
son2002	6.63	6.64	6.76	6.75	6.83	6.93
son2004	3.48	3.49	3.50	3.50	3.51	3.59
son2008	4.76	4.75	4.78	4.77	4.81	4.80
son2009	3.52	3.59	3.61	3.62	3.62	3.64
son2010	3.82	3.91	3.95	3.95	4.07	4.14
son2011	4.98	4.98	5.01	5.01	5.05	5.11
son2012 ²	11.56	10.74	9.50	11.16	9.86	10.09
Mean*	4.61	4.61	4.60	4.60	4.59	4.58
COV**	50.92%	48.57%	46.11%	48.78%	45.72%	45.43%

Notes: Values are in 2014 USD. ¹Shortfall scenario. ²Extreme shortfall scenario. *Weighted mean based on representative probabilities. **Coefficient of variance.

Comparing the price results between waiver scenarios 3 and 4 provides an excellent opportunity to compare the relative impacts between a large waiver, implemented in the worst production years and smaller waivers implemented in the years experiencing minor production setbacks. For instance, scenario 3 waives 2 billion gallons only in the 2012 state of nature, while scenario 4 implements a 1 billion gallon waiver in both the ‘shortfall’ and ‘extreme shortfall’ situations. Table 6 shows the nearly 20% reduction in corn price given an ‘extreme shortfall’ occurrence in scenario 3, when a 2 billion gallon waiver is implemented only in the 2012 representative state of nature. On the flipside, in the ‘moderate shortfall’ situations, 1993 and 1995, prices increase 3% and 6%, respectively. Comparing this situation to the scenario 4 waiver of a 1 billion gallon reduction in all ‘shortfall’ and ‘extreme shortfall’ conditions, prices in each representative ‘moderate shortfall’ year fall substantially, both over 7%. As noted, the waiver is still implemented for the ‘extreme shortfall’ case for 2012; however the price relative to no waiver is only reduced 3.8%.

Table 6 shows that average overall price when comparing scenarios 3 and 4 are essentially identical. Thus, when considering the probability of each states occurrence relative to the magnitude of the price movement, the price changes described earlier are offsetting in regards to the expected levels. The variability of corn price was measured by the coefficient of variation (COV) for each scenario, presenting a noteworthy difference between scenarios 3 and 4 in Table 5. Due to the increased sensitivity of the corn price in ‘extreme shortfall’ situations relative to the ‘shortfall’ occurrences, the

COV was found to be lower in the case where the waiver amount is only applied to the worst shortfall year. Additionally, comparing scenarios 5 and 6 show that the waiver impact on the 'severe shortfall' corn price is actually diminished as the waiver on 'shortfall' states is increased.

Table 6. Percent change from Base of U.S. Corn Price by Representative State of Nature given Smaller Waiver Scenarios

State of Nature	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)				
	2	3	4	5	6
son1979	0.0%	0.3%	0.3%	0.3%	0.3%
son1993 ¹	0.3%	3.2%	-7.5%	-3.8%	-11.4%
son1995 ¹	2.4%	5.9%	-7.3%	-6.1%	-14.5%
son2002	0.2%	2.1%	2.0%	3.4%	5.0%
son2004	0.3%	0.7%	0.7%	0.9%	3.4%
son2008	-0.3%	0.5%	0.3%	1.2%	1.0%
son2009	2.0%	2.6%	2.9%	2.9%	3.7%
son2010	2.6%	3.9%	3.7%	7.4%	9.3%
son2011	0.0%	0.6%	0.6%	1.4%	2.7%
son2012 ²	-7.7%	-19.4%	-3.8%	-16.0%	-13.9%

Note: ¹Shortfall scenario. ²Extreme shortfall scenario.

It is interesting to note than many of the relationships found in using the relatively small waiver scenarios, of 2 billion gallons or less, began to change when larger waivers were considered. The significance of the 'extreme shortfall' waiver relative to a waiver also conditional on the 'shortfall' occurrence represented by scenarios 9 and 10 show this. Both scenarios have the same expected price, however in this instance our results when comparing the effectiveness of each scenario in reducing corn price variability becomes obscured. Table 7 presents the corn prices in all representative states of nature given the larger RFS waiver scenarios. As was the case earlier, the 1979 representative yield scenario was unresponsive to waiver changes due to excess corn production. As was the case with the prior scenarios, the COV continually decreased with the implementation of larger waivers, thus representing decreasing corn price variance. At the same time, expected corn price experienced a slight decline as the magnitude of the waivers increased. This minimal change causes the future long-run welfare change to

be almost zero. Table 8 is included to better represent the impacts of implementing a waiver relative to the baseline case without waivers.

Comparing scenarios 7 and 10 in regard to the ‘extreme shortfall’ circumstance further shows that the impact of a waiver is diminished given the addition of waivers conditional on the ‘moderate shortfall’ production occurrence. This was also the case found in the smaller waiver scenarios. When a 3 billion gallon waiver is implemented solely in the 2012 state, 2012 state of nature prices are expected to be reduced almost 30%, relative to 25% in the same situation but with a possible 3 billion gallon waiver also employed for the 1993, and 1995 states of nature. This interesting finding shows that the effectiveness of decreasing corn price by employing waivers in the extreme cases is reduced given additional waiver possibilities in less-extreme conditions.

Table 7. U.S. Corn Price by Representative State of Nature given Waiver Scenarios, 7-12

State of Nature	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)						
	Base	7	8	9	10	11	12
son1979	3.13	3.14	3.14	3.14	3.15	3.15	3.15
son1993 ¹	7.86	8.21	8.38	8.49	6.38	6.45	6.62
son1995 ¹	6.40	6.94	7.09	7.17	5.29	5.48	5.54
son2002	6.63	6.84	6.95	7.09	7.09	7.17	7.26
son2004	3.48	3.50	3.57	3.62	3.67	3.69	3.73
son2008	4.76	4.80	4.80	4.87	4.91	4.95	4.95
son2009	3.52	3.62	3.64	3.65	3.73	3.79	3.85
son2010	3.82	4.06	4.17	4.26	4.30	4.40	4.53
son2011	4.98	5.01	5.02	5.10	5.17	5.22	5.26
son2012 ²	11.56	8.46	7.09	5.61	8.82	7.26	5.88
Mean*	4.61	4.59	4.57	4.56	4.56	4.54	4.53
COV**	50.92%	44.42%	42.89%	42.22%	41.73%	39.07%	37.91%

Notes: Values are in 2014 USD. ¹Moderate shortfall scenario. ²Extreme shortfall scenario.

*Weighted mean based on representative probabilities. **Coefficient of variance.

Table 8. Percent change from Base of U.S. Corn Price by Representative State of Nature given Waiver Scenarios, 7-12

State of Nature	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)					
	7	8	9	10	11	12
son1979	0.3%	0.3%	0.3%	0.4%	0.5%	0.6%
son1993 ¹	4.8%	7.2%	8.6%	-20.6%	-19.6%	-17.3%
son1995 ¹	9.2%	11.7%	13.1%	-18.9%	-15.6%	-14.7%
son2002	3.5%	5.3%	7.5%	7.5%	8.8%	10.4%
son2004	0.7%	2.8%	4.5%	5.9%	6.6%	8.0%
son2008	0.8%	1.0%	2.5%	3.5%	4.5%	4.5%
son2009	2.9%	3.6%	3.8%	6.5%	8.4%	10.2%
son2010	6.9%	10.0%	12.7%	13.7%	16.8%	20.4%
son2011	0.6%	0.9%	2.5%	4.0%	5.1%	6.1%
son2012 ²	-29.3%	-42.2%	-56.2%	-25.8%	-40.6%	-53.6%

Note: ¹Moderate shortfall scenario. ²Extreme shortfall scenario.

Since corn prices are dependent on the actions of producers in the market, both effects should be simultaneously assessed. A previous meta-analyst was conducted; evaluating 18 long-run ethanol studies to decrease on the ethanol mandates (Condon 2013). Although such analyses did not consider production dependent waiver policy implications, producer response to changes in mandates given all future production instances were found. Comparing the predicted long-run price changes found in this research to the results of this previous research finds both similarities and differences. The researchers found long-run implications of ethanol mandates have smaller impacts relative to short-run cases. Comparing the current results to those in the previous chapter verifies this intuitive result. Also, the meta-analysis found that on average each billion gallon increase in biofuel mandates increase the long-run corn price by 2-3%. Our results and waivers were dependent on the stochastic yield framework, and the magnitude of this relationship was seen to be impacted by production levels. The mean price was not found to increase at the 2-3% rate given 1 billion gallon reductions to the mandate, although in our instance, these were only implemented during poor crop years. In good crop years, when waivers were not implemented, resulting corn acreage reductions from producer reaction actually caused corn price to increase.

Acreage Results

Producer response to policy and future production expectations are pivotal in this analysis. This section presents the key findings in terms of acreage adjustments. Table 9 shows the planted acres in millions of acres for the important U.S. crops by scenario. It is important to point out that crop acres are determined before the yield state of nature is determined, thus are constant across all of the stochastic yield states. They are however impacted by the changes in future expectations, in this case, affected by the ethanol waiver policy. If corn producers expect large ethanol waivers in years of a poor corn crop, the expected future corn price is reduced, limiting the incentive for production. Most evident from this table is the steady decline in corn acreage given RFS policy alternatives with increasing waiver size. This cropland is then allocated to alternative uses, including those included in the table, as well as cropland pasture, rangeland, and an assortment of other crops.

Table 9. Stochastic Model U.S. Crop Acreage in Millions of Acres from 1975 Regressions

Crop	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)											
	Base	2	3	4	5	6	7	8	9	10	11	12
Corn	96.1	95.7	95.4	95.2	94.8	94.6	94.9	94.5	94.3	93.9	93.4	93.3
Soybeans	92.3	92.3	92.3	92.2	92.2	92.3	92.4	92.3	92.5	92.3	92.4	92.6
Wheat*	44.7	44.9	45.3	45.9	46.2	46.4	45.9	46.4	46.5	47.1	47.3	47.6
Cotton	22.9	22.5	22.2	22.0	21.6	21.2	21.4	20.8	20.6	20.9	20.4	20.3
Sorghum	7.3	7.4	7.3	7.3	7.5	6.9	7.9	7.6	7.2	7.6	7.6	7.5

Note: *Includes hard red winter, soft red winter, durum, and hard red spring varieties.

Producer response to decreased expected future corn price primarily shows an increased utilization of wheat to replace the corn acreage. Soybean acreage shows a surprising decrease in acreage as the waivers become more substantial likely due to rotation concerns. The results for cotton also show declines. Sorghum was found to have conflicting results between the two regression scenarios, as shown in Table 10, decreasing relative to the waiver size in the 1975 instance and increasing in the 1980 case. The 1980 case also found an absence of production response to the 1 billion gallon waiver used in scenario 1, relative to the four hundred million corn acre response using the 1975 regression.

Table 10. Stochastic Model U.S. Crop Acreage in Millions of Acres from 1980 Regressions

Crop	Conventional Ethanol Waiver Scenarios (Billion Gallons of Waiver)											
	Base	2	3	4	5	6	7	8	9	10	11	12
Corn	97.5	97.5	97.2	97.0	97.1	96.7	96.6	96.0	95.7	96.0	95.5	95.0
Soybeans	91.2	91.2	91.1	91.2	91.2	91.1	91.2	91.4	91.7	91.0	91.0	91.5
Wheat*	43.7	43.7	43.6	43.7	43.7	43.8	43.8	43.5	43.6	43.9	44.0	44.7
Cotton	23.0	23.0	23.0	23.2	23.1	23.2	23.3	22.5	23.0	23.3	22.9	22.8
Sorghum	6.8	6.8	6.8	6.6	6.7	6.6	6.7	6.5	6.4	6.6	6.4	6.4

Note: *Includes hard red winter, soft red winter, durum, and hard red spring varieties.

4. Discussion

Expected 2015 corn prices were found to slightly decrease with the implementation of larger waiver policies. However, the coefficient of variation in expected long-run 2015 corn price decreased consistently with larger waiver implementations. With respect to small waivers, implementing only in extreme production shortfall conditions was found to reduce corn price variance more effectively relative to a waiver implemented also in less-extreme cases. This is an important finding due to the non-included administrative burden of a policy option enacted more frequently. Larger waiver implementation, in regards to enacting such policy only under extreme conditions, created similar production responses, however presented mixed results relative to a situation where a less extreme waivers were implemented more often. These results depict the market sensitivity towards production variability, presenting a wide range of supply and demand balance circumstances attributed to the stochastic nature of yields. Conventional ethanol mandates, relatively unimportant during years of high yields, present major challenges during production short-fall events. The policy options in this chapter present tools in which we can use ethanol policy to mitigate the economic risk caused by variable crop production.

According to the USDA, as of 2012, almost half of the U.S. corn crop was being used to produce ethanol with further expansion in the biofuel mandate expected although only a small amount pertaining to conventional ethanol. With the highly fluctuation nature of total U.S. corn crop production but the relatively fixed amount of corn ethanol required, the economic impacts caused by the current RFS policy is of importance to domestic and international stakeholders. Food production sustainability, food security and food affordability should be kept in high regard when assessing the impacts of renewable fuel programs.

This research was designed to investigate the short- and long-run economic implications of the EPA using conventional ethanol waiver policy during large production shortfalls. In order to conduct this research, the first step involved construction of a stationary yield distribution that is assumed to

characterize the future with identification of production shortfall conditions. This was done using an econometric procedure over historical yield data. . Subsequently that distribution was used in modeling to analyze short- and long-run RFS relaxation implications. The short-run analysis was based on a shortfall of similar magnitude to that experienced during the drought of 2012, under the RFS requirements as contemplated for 2015, when conventional RFS ethanol mandates reach their upper-bound of 15 billion gallons. In the short run analysis we assume the corn crop is known and fixed so there is no producer response to mandate changes. In that case, significant impacts on prices, production levels, linked markets, and welfare were observed. The mandate relaxations greatly limited the magnitude of price spikes and livestock feeding costs plus redistributed welfare from producers to consumers. The waiver policy was found to reduce short-run total welfare \$18-\$25.4 billion USD.

Although previous research has found that biofuels can be associated with 40% of the increase in corn prices, it is important to note that in the short-run and long-run analyses herein, the results did not suggest elimination of biofuels completely from the market (Searchinger et al. 2008). In the short-run analysis across all scenarios, corn ethanol production was reduced to levels between 4.1-4.9 billion gallons, signaling that production would continue in shortfall conditions without government mandates, but at a much reduced level.

The implications of implementing such a policy over the long run were also investigated. In this instance, market participants would anticipate that waivers would occur when production was low. This was done using a stochastic model that simulated the market under a distribution of yields. In that model, producer decisions were assumed based on the full yield distribution and associated prices. Also, constraints reflecting mandate requirements were altered, conditional on yield shortfalls, with less required under 'shortfall' and 'severe shortfall' years. The primary findings of the long-run analysis illustrated that potential welfare gains could result from such a policy. Price spikes were reduced while expected prices were found to be minimally impacted due to the producer response of decreasing corn acreage. The long-run economic results present a potential for economic gains, stressing the importance of RFS policy risk on agricultural markets.

Across all of these results a philosophical question arises. The U.S. RFS legislation states goals of independence and security in its fuel source. The question is should a similar requirement be in place for the caloric energy needs of the U.S. populace? Moreover, should this be protected under production shortfalls?

5. Conclusions

RFS relaxation was found to have a significant impact on reducing price spikes and livestock production impacts due to reduced feeding costs when shortfalls occur. The reduction in producer welfare was found to be greater than the benefits consumers through decreased commodity prices, resulting in an overall negative welfare impact when considering only the agricultural impacts. In the long-run scenario, relaxation of the RFS reduces price variability during production shortfall years and stimulates a producers to decrease corn acreage, causing corn prices in non-shortfall years to increase. Overall this results in a negligible impact on expected average long-run corn prices, while reducing corn

price variability. The model findings demonstrated that positive risk reduction implications could exist from a production-dependent conventional ethanol waiver, with limited long-run changes to future expected prices.

We would like to conclude this manuscript with a discussion of two limitations and opportunities for future research within this realm. Restricting technological growth to follow a linear or log function is a restrictive assumption due to the non-uniform nature of agricultural technology improvements over time, especially considering more-recent developments in biotechnology. This concern prompted the implementation of several time horizons in the analysis, incorporating the same functional form application using modern observations. Since the ultimate goal of this exercise was to compare crop yield variability over-time, including variables other than a simple time trend was not conducted, as the following analysis required all forms of yield variability be captured in the states of nature in order to best reflect potential future outcomes. Unlike yield forecasting models, the purpose of the regression analysis was not to explain the dependent variable through a regression of explanatory data; however it was to quantify the impact of the forces that caused yields to vary within a period. The issue of technological change regarding the relationship between these inter-annual affects and their subsequent impacts on yields over time will also be discussed. Given access to increased computing abilities, quadratic time trend terms could have also been incorporated in the regressions to alleviate the linear/log restrictions on technological growth.

Secondly, heteroscedasticity could exist in yield data, particularly for crops that have recently experienced multi-gene genetic improvements in drought resistance. This is also the case for recent developments in herbicide and pesticide resilience, and any crop whose stress tolerance has been improved. Although such improvements would result in higher yields (Tollenaar and Wu 1999), variability could also become reduced. Researchers have also found that since crop varieties have become increasingly similar and more spatially correlated, yield variance has actually increased (Hazell 1984). The recent release of a new variety of drought resistant corn, given commercial success, would limit the ability of past observations in crop variability to forecast future impacts on production. Given adequate time for data regarding these crops effectiveness against drought conditions to be investigated, future research should incorporate this into projections on future crop variability. Since such commercial level data over a number of years is currently unavailable, this research will utilize the scenario analysis framework, incorporating differing log and linear yield growth rates dependent on the regression period. Corn production data is shown in Figure 4, although not used for the regression analysis; it shows a slight convergence in regard to variability ignoring the existence of the 2012 crop year, however this is not decisive. In order to visually inspect for heteroscedasticity in yields, the data for each state and crop would need to be separately tested rather than a test at the national and/or crop specific level.

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