THREE ESSAYS ON U.S. BIOFUEL AND FOOD SECURITY

by

NA HAO

(Under the Direction of Michael Wetzstein)

ABSTRACT

The dissertation is comprised of three essays entitled: Food before Biodiesel Fuel; Drought, Ethanol, and Livestock; and U.S. Ethanol and World Hunger: Is there a Connection? The aim of the dissertation is to assess the impact of U.S. bioenergy industry on domestic and world market through different dimensions. The first two essays are to link vertically the biofuel, food, and livestock market, the third paper is to link horizontally U.S. corn market and world market.

INDEX WORDS: U.S. biofuel, price transmission, world food market, agricultural market, U.S. corn

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NA HAO

BA, NANJING AGRICULTURAL UNIVERSITY, China, 2008

MS, UNIVERSITY OF GEORGIA, U.S., 2013

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NA HAO

Major Professor: Michael Wetzstein
Committee: Greg Colson
Berna karali

Electronic Version Approved:

Julie Coffield
Interim Dean of the Graduate School
The University of Georgia
May 2015

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CHAPTER 1

INTRODUCTION

The dissertation is composed on three essays entitled: Food before Biodiesel Fuel; Drought, Biofuel, and Livestock; and U.S. Ethanol and World Hunger: Is there a Connection? The aim of the dissertation is to assess the impact of U.S. bioenergy industry on domestic and world market through different dimensions. The first two essays are to link vertically the biofuel, food, and livestock market, the third paper is to link horizontally U.S. corn market and world market.

The first essay is in the context that a rapid growth in biodiesel has raised concerns about its impact on the price level and volatility of agricultural commodities. This is in junction with biodiesel government programs. Results indicate that policies affecting the soybean markets will have a long-run impact on biodiesel prices and having a biodiesel tax credit in place results in lower biodiesel prices but no impact on soybean prices. Given the objective of the tax credit to bolster the biodiesel market without distorting the agricultural sector, this is a positive result, and thus a support for biodiesel subsidies.

The second essay examines the biofuel policy validity of the recent EPA rejection for a waiver of the Renewable Fuel Ethanol Mandate. The waiver was requested by livestock producers due to rare 2012 Midwest drought. Results indicate linkages between drought and commodity markets, which generally supports EPA's conclusions. A waiver relaxing the biofuel mandate would have minimal impact on crop and livestock prices.

The final essay, U.S. Ethanol and World Hunger: Is there a connection?, is the first attempt in the literature addressing the issue with a Panel SVAR method. Results are presented on empirically testing the consequences of a U.S. ethanol demand on food prices in developing countries by employing a Panel Structural Vector Autoregression (Panel SVAR), which is newly developed in 2013. Global institutions could make prediction and direct food aid policies toward the consequences of biofuel production in U.S. Results indicate U.S. ethanol demand does not affect world prices as much as U.S. corn price, and coastal countries are more vulnerable to U.S. ethanol demand.

CHAPTER 2

FOOD BEFORE BIODIESEL FUEL

1. Introduction

Biodiesel is a vegetable oil- or animal fat-based diesel fuel used in standard diesel engines that is distinct from vegetable and waste oils used to fuel converted diesel engines. Biodiesel is typically blended with petrodiesel as a commercially viable, renewable, low carbon pure petrodiesel replacement fuel. With its continued annual growth rate of over 20% globally and 15% in the United States over the past decade, biodiesel has the potential to make an important contribution to national energy security and the environment (Biodiesel, 2012; EIA, 2012). It not only increases energy security and reduces harmful air emissions, but also improves public health and provides safety benefits (AFDC, 2012). With the potential for biodiesel to displace imported oil and improve local and global environmental conditions, the U.S. federal government has provided an array of incentives for biodiesel production (tax credits, project grants, and loan guarantees) resulting in a rapid rise in production (DOE, 2013). Furthermore, biodiesel is playing an important role in meeting the goals of the Renewable Fuel Standard, RFS2 (see EPA, 2010). In particular, biodiesel is the most versatile biofuel in the program because it can generate three types of RINs (biomass based diesel RINs, advanced biofuel RINs, and conventional biofuel RINs). Within the United States, over 860 million gallons of biodiesel were produced in 2011, which was driven by the RFS2 biomass-based diesel mandate (EPA, 2010), compared to 13,900 million gallons of ethanol (RFA, 2012). Although biodiesel production is less than 10% of ethanol, biodiesel production doubled from 2010 to 2011 (EIA, 2012). The growth rate of biodiesel has surpassed the growth rate of corn based ethanol, which is already close to meeting its full mandated level of 15 billion gallons in 2015.

While biodiesel presents a commercially viable opportunity to reduce dependence on imported fossil fuels, the use of biomass (e.g., soybeans, corn) for the production of fuels instead of food has raised a number of concerns. Foremost are fears that funneling agricultural crops into the energy sector, rather than the food sector, may impact the price level and volatility of agricultural commodities. There are concerns that biofuels and the policies that support them may be a prominent driver of recent food price spikes (see Abbott et al. 2008, 2009, 2011 for detailed annual assessments of the drivers of food prices).

Specifically, the rapid growth of biodiesel has raised concerns about biodiesel's impact on the price level and volatility of soybean prices (Babcock, 2008; Haines and Van Gerpen, 2012). Biodiesel production uses only the soybean oil, which is normally extracted from the beans before feeding the soymeal to livestock. Thus, use of soybean oil for biodiesel does not prevent animals from eating the soymeal left after the oil is extracted. However, soybean oil prices reached record highs in the summer of 2012 and biodiesel mandates may have had an impact on the global prices of vegetable oil and oilseeds. This directly impacts importing cooking oil countries such as Haiti and exporting countries such as Indonesia, the European Union's (EU) main source of biodiesel (according to Oxfam, 2012, in the EU, 80% of biofuel is biodiesel). Within the U.S., soybean oil used in biodiesel has basically offset the amount lost in food uses due to recent changes in trans-fat labeling requirements (ASA, 2008).

Biofuel policies are non-trivial and are very likely to have impacts that extend beyond the biofuel industry (Serra and Zilberman, 2013). Understanding and predicting price relationships between energy and agricultural commodities will lead to better policy. In this spirit, the aim is to investigate both the short- and long-run relationships between biodiesel and agricultural commodity prices by employing time-series price data on biodiesel, petroleum diesel, crude oil, and soybeans. Thus, the effects on the agricultural sector, specifically soybean prices, from energy markets are investigated. The time-series model is augmented with exogenous foreign exchange rates and soybean speculation index along with a dummy variable to account for biodiesel tax-credit policy shifts. This is the first study of the biodiesel-agricultural commodity nexus in the U.S. This new evidence and focus on biodiesel complements the existing literature assessing the relationship between agricultural and energy markets.

The underlying hypothesis is that the price effects from the biodiesel market on soybeans are likely weak in the short- and long-run; a result that is in contrast to previous research that has considered the relationship between ethanol and corn (Du et al., 2011; Harri et al., 2009; McPhail et al., 2012; Serra et al., 2011; Zhang et al., 2010). This hypothesis is motivated by two features of the biodiesel market. First, despite recent growth, the biodiesel market remains relatively small. In 2011, approximately 7% of the oil from the U.S. soybean crop was diverted from agricultural commodities to biodiesel production (ERS, 2013). In contrast, approximately 40% of the 2011 U.S. corn crop was diverted for ethanol production. Second, given current production technologies, prices, and market forces the importance of soybeans for biodiesel production has declined substantially in recent years. Prior to 2007 soybean was the primary feedstock for biodiesel production, but its usage has progressively declined. A number of substitute biodiesel inputs including canola and corn oils and animal fats have become important feedstocks for the production of biodiesel. In 2007, soybean's share of the biodiesel feedstock was 80% and in 2009 it decreased to 49% before rebounding to approximately 57% in 2011 (McPhail et al., 2011; EIA, 2013). In contrast, approximately 95% of U.S. ethanol is refined from corn. Given (a) the small size of the biodiesel market relative to soybean production and (b) the presence of a number of other competitive substitute feedstocks for the production of biodiesel in the U.S., it is unclear whether it should be expected that there is a significant short- or long-run relationship between biodiesel and soybean prices.

To test this hypothesis market data are used to evaluate the relationship between biodiesel and soybean prices. Using a Vector Error Correction Model (VECM) the short- and long-run relationships between crude oil, diesel, biodiesel, and soybean prices are evaluated controlling for foreign exchange rates, speculation in the soybean market, and federal biodiesel tax credits. Overall, the results support the hypothesis. No evidence is found of a short-run causal linkage between soybean and biodiesel prices, but a long-run relationship is indicated. This suggests policies supporting the biodiesel market may not have consequences for the soybean markets. In contrast with previous research assessing the relationship between corn and ethanol markets, the results suggest one overarching energy policy across all biofuels may not be as effective as mixed policies based on different short- and long-run relations between alternative biofuels and agricultural commodities. Based on this hypothesis and supporting empirical results, potentially effective biofuel policies are delineated.

2. Literature

Despite the growing importance of biodiesel as an alternative motor vehicle fuel and concerns about the market impacts of diverting soybeans from traditional food uses to biofuel production, previous research has not assessed the relationship between biodiesel and soybean prices in the U.S. Instead, this relation is assumed exogenously based on theory and the supply and demand for biodiesel are calibrated based on historical market quantities and prices (Babcock, 2012). In international settings, a few studies have considered the emergent biodiesel market. Barros et al.

(2010) consider biofuels (ethanol and biodiesel) and food in Brazil as possible production outputs. Budgets are developed for each of the possible outputs to determine the subsidy required for adoption. In terms of biodiesel, they conclude it becomes less viable as the demand for vegetable oil raises. Hassouneh et al. (2012) and Busse et al. (2012) investigate the biodiesel market in Spain and Germany, respectively, using a VECM. The results by Hassouneh et al. (2012) indicate a positive correlation among biodiesel, sunflower, and crude oil prices. Multivariate local regressions indicate the speed of biodiesel adjustment toward the long-run equilibrium is faster when biodiesel is cheaper. Busse et al. (2012) investigate changing linkages between diesel and biodiesel prices and between rapeseed oil and soybean. They determine before 2005 and after late 2007, there is a strong relation between biodiesel and diesel prices. Within the 2005 to 2007 interval, biodiesel and rapeseed prices are interdependent. They find a long-run relation between biodiesel and diesel prices and among biodiesel, rapeseed, and soybean oil prices. Kristoufek et al. (2012) employ a taxonomy perspective to investigate the relation among prices of petroleum oil, gasoline, biodiesel, ethanol, and agricultural commodities (wheat, sugar cane, soybeans, and sugar beets). Their results indicate in the short-term biodiesel and ethanol are weakly connected with commodities. In contrast, in the medium-term, fuels and commodity prices are not connected. Biodiesel tends to the fuel branch and ethanol to the food branch.

In contrast to the sparse literature on biodiesel market effects on agricultural commodity prices, the corn-ethanol nexus has been widely investigated as part of the larger literature focusing on the food vs. fuel debate (for a review see Qiu et al., 2011). Recent literature employing a VECM, Vector Autoregressive (VAR) model, or other models assessing volatility concludes that energy markets have a short-run impact on the food market, but no long-run impact exists (Saghaian, 2010; McPhail, 2011, McPhail et al., 2012; Qiu et al., 2012; Nazlioglu et al., 2013). An exception is the findings by Serra et al. (2011) who find both a short- and long-run relationship between ethanol and corn prices, but the long-run relationship is not significant if the ethanol price shock occurs close to the ethanol industry equilibrium. In contrast to the conclusion by Serra and Zilberman (2013), who infer the literature indicates a long-run relation between energy and agricultural commodity prices, Nazlioglu et al. (2013) indicate in general that this causal link remains unclear. One possible reason for this inconsistency is realizing that not all forms of energy have the same impact on all agricultural commodity markets. As hypothesized, potential agricultural commodity price effects from, say, the biodiesel market may be fundamentally different than the effects from, say, the ethanol market.

3. Vector Error Correction Model (VECM)

When time-series data are non-stationary, a Vector Autoregressive (VAR) model can be represented by the following Vector Error Correction model (VECM):

$$y_t = \mu + \alpha\beta' y_{t-1} + \Gamma \Delta y_{t-1} + \sum_{k=1}^{3} \delta_k x_{kt} + \varepsilon_t, \qquad (1)$$

where Δy_t denotes a vector of the first differenced crude oil, diesel, biodiesel, and soybeans price series and x_{kt} is the kth exogenous variable representing the foreign exchange rate, speculation index, or biodiesel tax credits. Associated with the exogenous variables is the coefficient vector δ_k representing the impact of the exogenous variable x_k on the first-differenced price series. Vector μ comprises the intercept terms and the coefficient vectors α and β contain the adjustment and cointegration parameters, respectively. The coefficient vector represents the short-run effects with a lag length of two weeks, where the lag length is selected based on the likelihood ratio test.

4. Data

Weekly crude oil, diesel, biodiesel, and soybean price series are employed from December 12, 2006 to October 7, 2011. Diesel prices represent ultra-low-sulfur no. 2 diesel fuel and are computed as the average of weekly spot prices in New York Harbor, U.S. Gulf coast, and Los Angeles and obtained from the Energy Information Administration (EIA). The proprietary data on Oil Price Information Service (OPIS) rack biodiesel prices are acquired from the USDA. These represent the national average of B100 without RIN. Crude oil prices represent global spot price of West Texas Intermediate (WTI) in Cushing, Oklahoma. Soybean spot prices represent Central Illinois no. 1 yellow soybeans. Both crude oil and soybean prices are obtained from the Commodity Research Bureau (CRB).

Table 1 presents the summary statistics for the weekly price series. All the price series are skewed to the right with soybeans relatively closer to being normally distributed. As measured by the kurtosis, oil prices appear to have more of its variance resulting from infrequent extreme deviations relative to the other prices.

Table 1. Summary Statistics for Weekly Price Series

Prices	Mean	Minimum	Maximum	Standard Deviation	Skewness	Kurtosis
Crude Oil ($/barrel)	80.770	32.350	145.280	21.405	0.434	3.256
Diesel ($/gallon)	2.367	1.206	4.115	0.646	0.563	2.750
Biodiesel ($/gallon)	3.991	3.090	5.666	0.751	0.714	2.153
Soybeans ($/bushel)	10.645	6.275	16.185	2.261	0.102	2.078

Notes: Total number of observations for each price series is 252.

Table 2 lists the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root tests. The 10% critical value for ADF and Phillips-Perron tests are −2.57 and −11.20, respectively. As indicated in the table, all the ADF and Phillips-Perron test statistics are below their associated critical values in absolute value, implying the inability to reject the null hypothesis of a unit root.

Table 2. Unit Root Tests

Prices	Augmented Dickey-Fuller Test Statistic	Phillips-Perron Test Statistic
Crude Oil	−1.798	−5.888
Diesel	−1.515	−4.190
Biodiesel	−0.352	0.496
Soybean	−2.303	−7.746

Note: Calculated by authors.

Supporting these price series are data measuring foreign exchange rates, speculation in the soybean market, and federal biodiesel tax credit. The impacts of economic activities are measured through the Nominal Broad Dollar Index. Obtained from the Board of Governors of the Federal Reserve System, the index is a weighted average of U.S. foreign exchange values against the currencies of a broad group of major U.S. trading partners. These exchange values are correlated with other macroeconomic factors, including worldwide economic growth, which influence agricultural commodity prices (Abbott et al, 2011). In terms of energy price effects on agricultural commodity prices, the relative strength of the US dollar should be taken into account (Nazlioglu and Soytas, 2011 and 2012). Accounting for possible financialization of commodity markets, a speculation index is created by employing the commodity index traders' weekly positions on soybean futures contracts. Based on De Roon et al. (2000) and Sanders et al. (2004), the speculation index is defined as:

$$Speculation_t = \frac{Long_t - Short_t}{Long_t + Short_t}. \quad (2)$$

This index measures the net long position held by commodity index traders normalized by their total positions, which serves as a measure of speculative pressure in soybean markets. The trader positions data are obtained from the Commodity Index Trader Supplement reports released by the Commodity Futures Trading Commission (CFTC).

The biodiesel excise tax credit, first introduced in the U.S. Jobs Creation Act of 2004 is also included in the analysis. The biodiesel excise tax credit of $1.00 per gallon, established by the U.S. Jobs Creation Act of 2004, is designed to make biodiesel competitive with conventional diesel in the marketplace. Since 2007, the tax credit has temporarily lapsed and been retroactively reinstated twice by the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010, and the American Taxpayer Relief Act of 2012. A dummy variable taking the value of one during the periods in which the biodiesel tax credits were authorized and zero over the temporary lapse between January 1, 2010 and December 17, 2010 is employed to account for this tax credit structural policy shift.

5. Cointegration Results

As discussed by Engle and Granger (1987), a linear combination of two or more non-stationary series that share the same order of integration may be stationary. If such a stationary linear combination exists, the series are said to be cointegrated and long-run equilibrium relationships among those series exist. Although there may be short-run developments that can cause series to deviate, there is a long-run equilibrium relation represented as a linear combination, which ties the individual price series together.

The Johansen trace test for determining the presence of cointegration among the price series indicates two cointegrating equations as follows:

$$P_s = -585.721 + \underset{(5.288)}{13.005} P_b + \underset{(0.181)}{0.780} P_o \quad (3)$$

$$P_d = 39.137 - \underset{(0.385)}{0.348} P_b - \underset{(0.013)}{0.036} P_o \quad (4)$$

where P_o, P_d, P_b, and P_s are the price levels of crude oil, diesel, biodiesel, and soybeans, respectively and the numerical coefficients comprise the β vector of cointegration parameters in equation (1). The standard errors in parentheses indicate all the coefficients are significantly different from zero at the 1% or 5% level, except for the coefficient in equation (4) associated with the biodiesel price, P_b. From (3), soybean, biodiesel, and crude oil prices have a long-run relationship, and from (4), diesel and crude oil prices have a long-run relation.

Table 3. Weak Exogeneity Tests

Prices	Chi-Square Test Statistic
Crude Oil	44.423*
Diesel	41.057*
Biodiesel	38.496*
Soybean	18.235*

Notes: * indicates significance at the 1% level.

Table 3 lists the results of weak exogeneity tests indicating at the 1% significance level that all the price series are weakly exogenous to each other. This indicates a long-run causality among these prices.

6. Vector Error Corrections Model (VECM) Results

6.1. Long Run

Table 4 lists the estimates of the adjustment coefficient vectors, α, along with the error correction vectors, β. For crude oil and biodiesel prices the adjustment and error correction coefficients are significant at the 1% or 5% level, except for the biodiesel β_2 coefficient. In equation (4) and Table 4, the beta coefficient on the price of crude oil is relatively small but significant, indicating a slight long-run inverse relation between crude oil and diesel prices.

Table 4. Cointegrating Vector Results

Prices	Adjustment Coefficient Vectors		Error Correction Vectors	
	α_1	α_2	β_1	β_2
Crude oil	0.614*	6.795*	−0.780*	0.036*
	(0.178)	(2.567)	(0.181)	(0.013)
Diesel	0.004	0.008	---	1.000
	(0.005)	(0.066)		
Biodiesel	0.010*	0.130*	−13.005**	0.348
	(0.002)	(0.025)	(5.288)	(0.385)
Soybeans	−0.006	−0.248	1.000	---
	(0.020)	(0.287)		

Notes: Standard errors are in parentheses. * and ** indicates significance at the 1% and 5% level.

The adjustment coefficient, measuring the speed of adjustment to the long-run equilibrium, associated with crude oil prices for equation (4) is 6.795, indicating within one week the correction to crude oil to restore the long-run equilibrium overshoots the equilibrium. This may result from other factors impacting the market price of diesel (Thies and Brown, 2009). The refining process is different for diesel than for gasoline. When refining diesel, refiners first create distillate, which is further refined into off-road diesel (higher sulfur content) and home-heating oil. Distillate makes up approximately 25-30% of refining output with gasoline 40-50%. This range of distillates results in slippage within the oil- and diesel-price relation. In the winter months, distillates will be in the upper range and in the summer months increased demand for gasoline will lower the amount of distillates produced. This change in demand for different oil outputs may explain this slight negative β_2 coefficient and the overshooting of the equilibrium. Also, as refiners phased in the ultra-low-sulfur diesel in the mid-2000s, it significantly impacted diesel costs, which further eroded any positive oil/diesel price relation. There were also other structural shifts affecting the oil/diesel price relation. Early in 2008, China increased its demand for imported diesel to ensure no supply disruptions for the Beijing Olympics and they temporarily switched from coal to diesel to reduce pollution during the games. With the start of the Great Recession in the fourth quarter of 2008, diesel demand dropped sharply relative to gasoline with the shipment of goods falling double digits while consumer driving shrunk by much lower percentages. This resulted in a sharp drop in diesel prices relative to oil and gasoline prices. With the recovery, diesel prices again reacted differently relative to oil and gasoline prices.

Of particular interest is the long-run influence of soybean prices on biodiesel prices. A plausible explanation of this result is soybeans are an input in the refining of biodiesel, so a soybean price rise will shift the supply curve for biodiesel to the left resulting in an increase in the price of biodiesel. This result is in contrast to previous research investigating the corn and ethanol price relation. As outlined in the literature review, recent studies conclude that ethanol prices may have a short-run impact on corn prices, but no long-run impact exists. One explanation for this lack of long-run impacts is the competitive market will yield a supply respond to any short-run disequilibria and mitigate any possible short-run corn price spikes. The VECM results indicate such a market response may not occur for biodiesel. This is possibly the result of a fundamental difference in the biodiesel and ethanol markets. As addressed in the introduction, compared with ethanol the biodiesel market is relatively small in terms of its demand for soybean. Thus, the long-run relation of the soybean/biodiesel markets is fundamentally different than the corn/ethanol markets. As the results indicate, in the long-run the soybean market influences the relative small biodiesel market.

In contrast to the relatively large adjustment coefficient in the crude oil and diesel price long-run equilibrium, the adjustment coefficient for biodiesel associated with cointegration equation (3) is relatively small, 0.010. This indicates within one week only a 1% movement toward restoring long-run equilibrium will occur. Such a small speed of adjustment indicates the influence of the soybean market on biodiesel prices is not instantaneous. Biodiesel refiners appear to be slow in responding to soybean price hikes. This implies they may be reluctant to pass higher costs onto their customers. They may be facing a very elastic demand curve for biodiesel.

6.2. Short Run

VECM results for the short-run effects and exogenous variables are listed in Table 5 for each of the price series. Considering these short-run impacts, none of the change in lagged-price coefficients are significant at the 10% level in both the crude oil and soybean price equations. In the diesel equation, the change in the lagged-price coefficient for diesel itself is significant at the 10% level, and for the biodiesel equation both the change in lagged-price coefficients for crude oil and biodiesel prices are significant at the 1% level.

Table 5. Vector Error Correction Model (VECM) Results

Variables	VECM Equations			
	ΔCrude Oil Price$_t$	ΔDiesel Price$_t$	ΔBiodiesel Price$_t$	ΔSoybean Price$_t$
Constant	-0.005	0.173	0.239*	-0.010
	(6.667)	(0.170)	(0.064)	(0.745)
ΔCrude Oil Price$_{t-1}$	0.044	0.004	0.003*	0.017
	(0.119)	(0.003)	(0.001)	(0.013)
ΔDiesel Price$_{t-1}$	-7.768	-0.213***	-0.017	-0.456
	(4.857)	(0.124)	(0.047)	(0.543)
ΔBiodiesel Price$_{t-1}$	-8.585	-0.088	0.171*	-0.726
	(5.764)	(0.147)	(0.056)	(0.644)
ΔSoybean Price$_{t-1}$	-0.153	0.020	0.009	-0.050
	(0.655)	(0.017)	(0.006)	(0.072)
FX$_t$	-0.686*	-0.020*	-0.006*	-0.057*
	(0.126)	(0.003)	(0.001)	(0.014)
Subsidy$_t$	-0.823	0.007	-0.024*	0.046
	(0.792)	(0.020)	(0.008)	(0.089)
Speculation$_t$	-5.250	0.001	-0.105*	0.691***
	(3.729)	(0.095)	(0.036)	(0.417)

Notes: The estimated model is $\Delta y_t = \mu + \alpha\beta' y_{t-1} + \Gamma\Delta y_{t-1} + \delta_1 FX_t + \delta_2 Subsidy_t + \delta_3 Speculation_t + \varepsilon_t$, where y_t is vector of crude oil, diesel, biodiesel, and soybean prices, FX_t denotes the foreign exchange rate, $Subsidy_t$ is the federal biodiesel tax credit (0 for no subsidy and 1 for subsidy), and $Speculation_t$ represents speculation in the soybean market. Standard errors are in parentheses. *, **, and *** represent significance at the 1%, 5%, and 10% level, respectively.

Thus the only short-run influence is crude-oil prices influencing biodiesel prices. There is no direct short-run causal linkage between biodiesel and soybean prices. This result supports the underlying hypothesis of no strong relation between biodiesel and soybean prices due to the small size of the biodiesel market relative to the soybean market, the declining importance of soybeans as a feedstock for the production of biodiesel, and the viability of alternative feedstocks for biodiesel. Due to the availability of substitute feedstocks for the production of biofuels, in the short-run, price spikes in the soybean market are not passed through into the biodiesel market. Again this result is in contrast to the literature investigating the corn/ethanol price relation. As outlined in the literature review, research has generally identified a short-run impact of the ethanol market on the price of corn.

6.3. Exogenous Variables

As indicated in Table 5, among the three exogenous variables (foreign exchange rate, tax credit, and speculation) included in the model, the foreign exchange rate coefficient is negative and significant at the 1% level in all the VECM equations. When the exchange rate increases, the U.S. dollar is stronger relative to other currencies, so the import price of crude oil is cheaper. However, the relative increase in the exchange rate also results in U.S. exports becoming more expensive, which shifts the domestic demand for diesel, biodiesel, and soybeans downward, yielding lower prices.

The tax-credit dummy coefficient is negative and significant (at the 1% level) only in the biodiesel equation. Having a biodiesel tax credit in place decreases the production costs and thereby increases the supply, resulting in lower biodiesel prices. Interestingly, there is no evidence a biodiesel tax credit has an impact on soybean prices. Given the ambition of the tax credit to bolster the biodiesel market without distorting the agricultural sector, this is a positive result. It indicates there are no food-before-fuel impacts from subsiding biodiesel.

The coefficient for soybean speculation index is negative and significant at the 1% level in the biodiesel equation and positive and significant at the 10% level in soybean equation. As the speculative pressure from commodity index traders in the soybean futures market increases biodiesel prices fall and soybean prices increase. This result further reinforces the limited link between the soybean and biodiesel markets. Speculation in the soybean market driving up the price of soybeans does not appear to spill over into the biodiesel market. The lack of any short-run price relationships within these two markets and the slow speed of the long-run equilibrium adjustment of biodiesel prices to the soybean market is probably the cause of this lack of a spill-over effect. The presence of soybean speculation may be providing incentives for biodiesel refiners to seek out other biomass-soybean substitutes, which may be cheaper. As outlined in the introduction, this is consistent with the relative decline of soybeans used for biodiesel refining.

7. Biofuel Policy

In contrast to the findings in the bulk of the literature analyzing the long-run relationship between corn and ethanol, biodiesel prices do appear to have a long-run relation with soybean prices. For policy analysis, this conflicting result between the long-run relationships of soybeans and biodiesel compared to corn and ethanol indicates that not all alternative biofuels should be treated the same. One overarching biofuel policy and program may not be effective in promoting alternative energies efficiently. Specifically, if there are no long-run causations between ethanol and agricultural commodities, then long-run policies addressing the food before ethanol issues may not be required. Such long-run policies include food and ethanol subsidies, price controls, and export and import restrictions. Instead, allowing the free market to adjust to changes in crop usages with a constant infusion of public sponsored research may be all that is required. In contrast, for biodiesel, if there is a long-run relation, then some type of long-run policies may be required. With the results indicating soybean price increases being passed onto biodiesel prices, policies directed toward creating a sustainable biodiesel industry should consider this price movement. Free markets will not insulate the biodiesel market from soybean price volatility. A constant infusion of public sponsored agricultural research and outreach will mitigate soybean price volatility. However, if an infant biodiesel industry is to mature, it may also require being insulated from market volatility. Precautionary agricultural commodity buffer stocks, subsidized biofuel prices, government incentives and regulations favorable to biofuel production, and export restrictions may be warranted. A policy explicitly addressed in the model is a biodiesel tax credit. Results indicate the credit does boost the supply of biodiesel by lowering the price with no resulting spillover effect on soybean prices. If the objective is to support the infant biodiesel sector, then establishing and maintaining this credit policy over a number of years appears warranted as opposed to the current uncertain on and then off again policy regime. In any case, for an efficient set of alternative policies the short- and long-run relations between biofuel and agricultural commodities should be empirically determined.

8. Conclusion

Using weekly price data on crude oil, diesel, biodiesel, and soybeans, this study is the first to analyze the price relationship between the U.S. biodiesel and the soybean markets. In support of the initial hypothesis, no short-run relationship between soybeans and biodiesel is found. This result may be due to the small size of the biodiesel market relative to the soybean market, the declining importance of soybeans as a feedstock for the production of biodiesel, and availability of competitive substitute inputs (corn oil, canola oil, and animal fats). In the short-run, price spikes in the soybean market are not passed through into the biodiesel market. This result is in contrast to the majority of the literature focusing on the relationships between corn and ethanol. In the short-run, biodiesel prices are affected by the crude oil market, foreign exchange rate, speculation, and biodiesel tax credits. In the long-run, the soybean market is influencing biodiesel prices.

The dichotomy of the biomass/biofuel relation, supported by this research, raises questions on the overall nature of alternative fuel policies. Knowledge of the interaction among alternative fuel markets and their satellite input and output markets are necessary in developing policies and programs. As this research indicates, even within just one subset of alternative energies (biofuels), the markets for alternative biofuels can be quite different. This research suggests, once the short- and long-run spillover effects of markets are determined, tailored policies and programs may be required for particular alternative energies. Specifically, for bioenergy, policies including precautionary agricultural commodity buffer stocks, subsidized biofuel prices, government incentives and regulations favorable to biofuel production, and export restrictions may be warranted given a long-run influence of the soybean market on biodiesel prices. In contrast, if there is no long-run link between corn and ethanol markets, such long-run policies may not be warranted. The competitive market will yield an efficient set of prices.

CHAPTER 3

DROUGHT, ETHANOL, AND LIVESTOCK

1. Introduction

Despite advances in crop varieties, irrigation technologies, and weather forecasting, drought remains one of the most catastrophic supply shocks in modern agriculture. Although the globalization of the agricultural commodities improves the ability to blunt localized impacts of crop losses, the linkages of commodity, livestock, and nascent biofuel markets leaves multiple markets vulnerable to drought. The emergence of a substantial U.S. corn-based ethanol market has created growing conflict between the ethanol and livestock industry over corn supplies, particularly in times of negative corn supply shocks.1

The recent 2012 Midwest U.S. drought that severely impacted corn supplies and corn prices highlights this conflict as well as the government policies, which help support the U.S. ethanol industry. The historic drought conditions affecting the U.S. Corn Belt resulted in a 13% decline in corn yields from 2011, despite the record number of acres planted in over 75 years (USDA, 2013a). In 2012, the weighted-average farm price for corn was $7.10 per bushel compared with $6.22 in 2011 (USDA, 2013b). Such price spikes have a marked impact on the profitability and production decisions of livestock producers (Lawrence et al., 2008). The diversion of corn to ethanol production coupled with the drought was blamed by the popular press and the livestock industry for this corn-price spike and the hardships faced by livestock producers (Carter and Miller, 2012; Fletcher, 2012; NCBA, 2012a).

In response, ten state governors and major livestock groups (including the National Cattlemen's Beef Association and the National Chicken Council) requested in July 2012 that the Environmental Protection Agency (EPA) grant a short-term partial waiver of the Renewable Fuel Standard (RFS) mandates (EPA, 2012). The underlying rational for the waiver request was based upon the assertion that a relaxation of the ethanol-fuel mandate would lower corn prices for livestock producers by reducing the amount of corn flowing into ethanol, thus ultimately mitigating some of the economic hardship suffered by livestock producers. Such short-run relief would stabilize herd size, yielding long-run positive impacts on livestock prices. The EPA denied the waiver in November 2012 based upon their analysis indicating that with high probability a one-year relaxation of the mandate would have minimal (if any) impact on corn prices because the RFS mandate is not binding. Specifically, the EPA concluded that a one-year waiver would have little impact on the short-run supply and demand for ethanol, and hence corn prices and the quantity of corn used for ethanol production, because of (i) carryover of blending credits (RINs) from previous years, (ii) inelastic short-run demand and supply of ethanol, and (3) production difficulties in adjusting ethanol production in the short-run. This ruling was not well received by livestock groups who argued that the failure to provide short-term relief to the livestock industry in the face of record drought will have long-run impacts on livestock prices due to reductions in herds (NCBA, 2012b).

The conflict between the two primary end users of corn during the drought of 2012 highlights the interrelation of food and energy markets and the importance of government policy for addressing short- and long-long price volatility and food, energy, and environmental goals. Surprisingly, despite a substantial literature assessing the relationship between U.S. corn and ethanol markets, significantly less attention has been directed towards the relationship with the livestock market.

Previous research has not evaluated the general impact of drought and the intensity of drought on corn, ethanol, and livestock markets. Given the increased linkage between food and energy markets, understanding the impact of drought is particularly important under the specter of potentially increased temperatures and duration between rainfall events in the U.S. Corn Belt (Karl, Melillo, and Peterson, 2009).

This article evaluates the price linkages and transmission patters in the U.S. corn, soybean, ethanol, and livestock industry with special attention to the impact of drought conditions. Employing a vector error correction model (VECM) and a detailed drought severity classification developed by the U.S. Drought Monitor, this article presents the first evidence on the impact of drought across the corn, soybean, ethanol, and livestock markets. Through this analysis, several insights on potential policy solutions to supply shocks caused by drought are revealed. Critically, our analysis supports the short-run conclusions of the EPA that policies such as a RFS waiver will not provide significant relief to the livestock industry from volatile corn prices. Instead, our results indicate corn-supply policies may be a superior avenue for aiding the livestock industry when faced with corn-supply shocks. Policies directly augmenting supply may dominate policies providing incentives to reduce demand. Understanding the economic relations among markets will provide the direction that such policies should follow.

2. Literature review

The literature concerning ethanol-related transmission impacts is rapidly expanding (Campiche et al., 2010; Chang and Su, 2010; Zhang et al., 2010; Mcphail et al., 2011; Serra and Zilberman, 2013). For a review of the literature see Qiu et al., 2011. Recent literature employing a VECM, Vector Autoregressive (VAR) model, or other models assessing volatility generally concludes energy markets have a short-run impact on the food market, but no long-run impacts (Saghaian, 2010; McPhail, 2011; McPhail et al., 2012; Qiu et al., 2012; Nazlioglu et al., 2013). An exception to this finding is Serra et al. (2011) who find both a short- and long-run relationship between ethanol and corn prices, and the conclusion by Serra and Zilberman (2013) inferring the literature indicates a long-run relation between energy and agricultural commodity prices. Nazlioglu et al. (2013) indicate in general this causal link remains unclear. Omitted variable bias may explain some of this inconsistency. As hypothesized, climatic environmental conditions play a role in agricultural commodity prices and failure to consider these conditions may affect the commodity/biofuel price relations. Although there is research introducing climate impact into corn markets, climate impacts on biofuel and livestock markets are far from fully considered (Differnbaugh et al., 2012).

Diffenbaugh et al. (2012) project 21st century changes in temperature and precipitation, simulate the response of U.S. corn yields, and use a GTAP model to simulate the volatility in corn prices. Their research concludes that U.S. corn-price volatility will increase sharply in response to global warming projected over the next three decades. However, their analysis is limited in terms of only investigating the impact of climate (indexed by temperature and precipitation) on corn-price volatility. The possible spillover effects to the livestock market are not addressed. Their analysis could be extended by investigating the mechanisms of how climate affects livestock and biofuel markets. The time-series model developed below is an attempt to extend this investigation.

In contrast to extensive literature on ethanol-market effects on crop-commodity prices, their effects on livestock markets have not been as widely investigated. Tejeda (2012) employed a multivariate regime-switching model, and found significant positive dynamic correlations among weekly price changes of DDGS, corn, and soybean meal. Various time-series models are employed to investigate the dynamic interaction among grains and livestock prices (Anderson et al., 2008; Pozo et al.,2012;Tejeda and Goodwin, 2009; Tejeda and Goodwin, 2011). Miljkovic, et al. (2012) employ a simultaneous equation model and determine ethanol policy may indirectly impact cattle production through the RFS's influence on corn quantity. Bhattacharya, et al. (2009) and Elobeid, et al. (2006) employ a multi-market equilibrium displacement model to account for interdependence. Six markets are considered: beef, pork, poultry, corn, ethanol, and ethanol byproducts.

However, the literature is void on accounting for drought and its impacts on agricultural and biofuel markets. The relation of drought, biofuel, and livestock is still elusive. Without knowing their relations it is not possible to fully assess the impacts of a RFS waiver. As a first attempt to fill this void, the transmission effects among the markets, by including drought effects and ethanol prices, are investigated. With such a model, the policy of adopting the RFS waiver can then be evaluated.

3. Vector Error Correction Model (VECM)

When time-series data are non-stationary, a vector autoregressive (VAR) model can be represented by the following vector error correction model (VECM) with exogenous variables:

$$\Delta y_t = \mu_t + \alpha\beta' y_{t-1} + \Gamma \Delta y_{t-1} + \sum_{k=1}^{10} \delta_k x_{k,t} + \varepsilon_t. \quad (5)$$

Where Δy is a vector of first-differenced log-transformed ethanol, corn, soybean, beef, and poultry real prices, adjusted by the CPI, andx_kt is the kth exogenous variable representing the drought indicator, seasonal dummies, interaction terms of drought with seasonal dummies, speculation prices of corn and soybeans, and dollar prices. Associated with the exogenous variables is the coefficient vector δ_k representing the impact of the exogenous variable x_k on the first-differenced logarithm price series. Vector μ comprises the intercept terms and the coefficient vectors α and β contain the adjustment and cointegration parameters, respectively.

The coefficient vector   represents the short-run effects with a lag length of two weeks, where the lag length is selected based on the model selection criteria Akaike information criterion (AIC)and Schwarz Bayesian information criterion(SBC). The model selection methods, AIC and SBC are also employed to determine rank number.

The drought variable is acquired from the U.S. Drought Monitor, a synthesis of multiple indices and impacts, which represent a consensus of federal and academic scientists. The Drought Monitor concept was developed (jointly by the National Weather Service, the National Drought Mitigation Center, and the U.S. Department of Agriculture's Joint Agricultural Weather Center in the late 1990s) as a process that synthesizes multiple indices, outlooks, and local impacts, into an assessment that best represents current drought conditions. No single definition of drought works for all circumstances, so a drought index is employed to detect and measure droughts (Drought Monitor, 2013). The index was designed to heighten awareness of drought through a single product by measuring its intensity from D0 to D4, with D0 being the least and D4 being the most intense. Drought intensity categories are based on five key indicators (the Palmer drought index, soil moisture, stream flow, and precipitation, along with short and long-run drought indicator blends) and numerous supplemental indicators based on regional and seasonal characteristics (North American Drought Monitor, 2013). The accompanying drought severity classification indicating ranges for each indicator for each dryness level is listed in Table 1. For the analysis, the percentage of Midwest with 80% of the corn production, which falls into the categories of D3 and D4, is employed as the indicator of drought.

When a drought occurs within two weeks, it is assumed corn and soybean prices are affected through the commodities future markets. McPhail et al. (2012) determined within one month, any speculative demand impacts on crop prices are mainly accounted for. In accordance with their results, moving averages of two, four, and six periods (weeks) for drought categories D3 and D4 (D3/D4) are modeled individually. All the moving averages yield similar results, with the two-period moving average employed as representative. According to the model selection criteria, AIC and SBC, the two-period moving average with the D3/D4 index is the appropriate model specifications.

As outlined by Flaskerud and Johnson (2000), there are also possible seasonal effects on prices. In (1) these seasonal impacts are modeled as seasonal dummies. According to USDA (2010), within the Midwest, the planting season is defined as March through June, the growing season July and August, and the harvest season from September through November. Seasonal drought effects are captured by interaction terms of seasonal dummies with theD3/D4 drought variable.

The net long position held by commodity index traders, normalized by their total positions, serves as a measure of speculative pressure in corn and soybean markets. Based on De Roon et al. (2000) and Sanders et al. (2004), this speculation index is defined as:

$$\mathrm{Speculation_t} = \frac{\mathrm{Long_t} - \mathrm{Short_t}}{\mathrm{Long_t} + \mathrm{Short_t}} \qquad (6)$$

The trader positions data are obtained from the Commodity Index Trader Supplement reports released by the Commodity Futures Trading Commission (CFTC).

In terms of energy price effects on agricultural commodity prices, the relative strength of the U.S. dollar should be taken into account (Nazlioglu and Soytas, 2011 and 2012). The impacts of economic activities are measured through the Nominal Broad Dollar Index. Obtained from the Board of Governors of the Federal Reserve System, the index is a weighted average of U.S. foreign exchange values against the currencies of a broad group of major U.S. trading partners. These exchange values are correlated with other macroeconomic factors, including worldwide economic growth, which influence agricultural commodity prices (Abbott et al, 2011).

4. Data

For the ethanol-fuel market, weekly U.S. ethanol prices are obtained from the Energy Information Administration (EIA) from January 2006throughDecember 2012. Nominal corn, soybean, beef, and poultry spot weekly prices are acquired from the Commodity Research Bureau. Nominal prices are adjusted by the Bureau of Labor Statistics Consumer Price Index, with 1982-1984 as the baseline year (Table 6).

Table 6. Summary statistics of the fuel, grain, and livestock markets

Real Prices	Mean	Standard Deviation	Skewness	Kurtosis	Minimum	Maximum	ADF[a] test p-value
Ethanol ($/gallon)	1.07	0.19	0.88	5.07	0.78	1.86	0.34
Corn ($/bushel)	2.19	0.71	0.27	1.93	1.00	3.77	0.45
Soybeans ($/bushel)	4.85	1.28	-0.08	2.18	2.51	7.81	0.42
Beef ($/pound)	0.45	0.05	0.52	2.27	0.37	0.56	0.49
Poultry ($/pound)	0.39	0.02	-0.79	2.83	0.33	0.43	0.91

[a] ADF is the Augmented Dickey-Fuller test, which tests the presence of a unit root. The null hypothesis is the existence of a unit root. The null hypotheses cannot be rejected at the 5% level, thus unit roots may exist for each of the price variables.

Table 6 also lists the Augmented Dickey Fuller tests for all price series after a log transformation. The results are stable when changing the lag number from 1 to 12, thus indicating the inability to reject the presence of a unit root at a 5%significance level. This suggests the presence of non-stationary price series, which motivates the use of a vector error correction model (VECM) model.

5. Cointegration Results

As discussed by Engle and Granger (1987), a linear combination of two or more non-stationary series that share the same order of integration may be stationary. If such a stationary linear combination exists, the series are said to be cointegrated and long-run equilibrium relationships among the series exist. Although there may be short-run developments that can cause series to deviate, there is a long-run equilibrium relation represented as a linear combination, which ties the individual price series together.

The Johansen trace test for determining the presence of cointegration among the price series indicates two cointegration equations

$$Pe = 21.684 + \underset{(0.141)^{**}}{0.282Ps} + \underset{(0.250)^{*}}{0.486Pb} - \underset{(0.644)^{***}}{2.921Pp} \quad (7)$$

$$Pc = -4.395 + \underset{(0.099)^{***}}{0.910\,Ps} + \underset{(0.177)^{***}}{1.031Pb} - \underset{(0.456)}{0.499Pp}. \quad (8)$$

Where Pe, Ps, Pb, Pp, and Pc are the log transformed prices of ethanol, soybean, beef, poultry, and corn respectively and the coefficients comprise the β vector of cointegration parameters in (1). The standard errors in parentheses indicate all the coefficients are significantly different from zero at the 10% (indicated by *), 5% (indicated by**), or 1% (indicated by ***) level, except for the coefficients associated with the poultry prices in (8). From (7), ethanol, soybean, beef, and poultry prices have a long-run relationship, where ethanol prices have a positive relation with soybean and beef prices and a negative relation with poultry prices. From (8), corn, soybean, and beef prices have a long-run relation, where both soybean and beef prices have a positive relation with corn prices. There is no significant long-run price relation between ethanol and corn. As discussed in the literature review, this result is consistent with most of the previous literature. This literature suggests one explanation for this lack of long-run impacts is the competitive market will yield a supply respond to any short-run disequilibria and mitigate any possible short-run corn price spikes.

6. Vector Error Corrections Model (VECM) Results

6.1. Long Run

Table 7 lists the estimates of the adjustment vector α. The α coefficient of cointergration associated with (7) on the ethanol, corn, and soybean prices are significant at the 1% and 5% level, indicating these prices are being affected by ethanol, soybean, beef, and poultry prices in the long run. The α coefficients of cointegration associated with (8) on the price of beef and poultry are significant at the 1% level, indicating these prices are being affected in the long run by corn, soybean, and beef prices.

Table 7. Cointegrating vector results

Prices	Adjustment Coefficient Vectors α	
	Equation 3a	Equation 3b
Ethanol	−0.054***	0.011
	(0.013)	(0.016)
Corn	−0.066**	−0.044
	(0.022)	(0.027)
Soybean	−0.060***	0.030
	(0.017)	(0.022)
Beef	−0.003	0.041***
	(0.010)	(0.013)
Poultry	0.002	0.010***
	(0.002)	(0.003)

Note: Standard Errors are in parenthesis with *, ** and *** denoting significance at the 10%, 5% , and 1% level, respectively.

The adjustment coefficients for prices associated with (7) and (8) are all smaller than one. In particular, for beef and poultry prices, the adjustment coefficients in (8) are 0.041 and 0.01, respectively, so within one week only a 4% and a 1% movement toward restoring long-run equilibrium will occur for beef and poultry prices, respectively. Such a small speed of adjustment indicates the inter-market transmission is not instantaneous. Beef and poultry producers appear to be slow in responding to the other price hikes. This implies they may be reluctant to pass higher costs onto their customers, which is supported by stable beef prices during the 2012 Midwest drought (USDA, 2013c).This apparent slow response may indicate why the livestock industry is concerned with grain-market price volatility. The slow adjustment suggests difficulties in passing input grain-price volatility onto their customers, which may account for some push toward a RFS waiver.

6.2. Short run

VECM results for the short-run effects and exogenous variables are listed in Table 4for each of the price series. Considering these short-run impacts, with corn a major input in the ethanol and poultry industries, corn prices are positively affecting ethanol prices, and poultry prices are influencing the corn market. In terms of the food before fuel debate, this short-run positive impact indicates a reversal. The ethanol industry is not influencing corn prices (the food before fuel issue) but instead corn is impacting ethanol. This result reinforces Nazlioglu et al. (2013) that the general causal link remains unclear. However, the results are consistent with recent market relations. Irwin (2013) concludes the current government policies of RFS mandates and EPAs restrictions on the percent of ethanol used for conventional gasoline (blend wall) results in corn prices driving ethanol prices. As indicated in Table 4, corn prices are influenced by drought and general economic activity. Previous research contained omitted variables accounting for drought and the livestock sectors and only recently incorporated speculation and macro indicators. Failure to account for these explanatory variables may lead to alternative results.

Table 8. Short-run and exogenous results of VECM

Variables	VECM Equations				
	ΔPe *t*	ΔPs *t*	ΔPc *t*	ΔPb *t*	ΔPp *t*
lnDrought*t*	0.004**	0.010***	0.008**	-0.002	-0.001
	(0.002)	(0.003)	(0.003)	(0.002)	(0.000)
lnDrought*t**grow	-0.005	-0.004	0.001	-0.001	-0.0002
	(0.003)	(0.005)	(0.006)	(0.003)	(0.001)
lnDrought*t**plant	-0.0002	-0.004	0.001	-0.001	-0.001
	(0.003)	(0.004)	(0.005)	(0.002)	(0.0005)
lnDrought*t**harvest	-0.006*	-0.009**	-0.011**	0.005**	0.001**
	(0.003)	(0.004)	(0.005)	(0.002)	(0.0005)
Lndollar*t*	-0.235***	-0.516***	-0.426***	-0.148***	0.027**
	(0.070)	(0.100)	(0.121)	(0.056)	(0.012)
Spesoy*t*	-0.077**	-0.172***	-0.131**	-0.061**	0.012**
	(0.034)	(0.046)	(0.058)	(0.027)	(0.006)
Specorn*t*	0.009	0.033	0.044	0.014	0.014**
	(0.036)	(0.049)	(0.063)	(0.029)	(0.006)
ΔPe*t-1*	0.404***	0.036	0.029	0.129**	-0.006
	(0.050)	(0.067)	(0.085)	(0.040)	(0.008)
ΔPc*t-1*	0.075*	0.103*	0.015	-0.048	-0.008
	(0.040)	(0.054)	(0.069)	(0.032)	(0.007)
ΔPs *t-1*	-0.005	-0.085	-0.072	0.046	0.001
	(0.049)	(0.067)	(0.085)	(0.040)	(0.008)
ΔPb *t-1*	-0.018	0.100	0.156	-0.038	0.011
	(0.066)	(0.089)	(0.113)	(0.053)	(0.011)
ΔPp *t-1*	-0.175	0.788*	1.201**	-0.138	-0.089*
	(0.327)	(0.442)	(0.561)	(0.263)	(0.054)
Grow	0.006	-0.003	-0.016	0.010	-0.000
	(0.008)	(0.011)	(0.014)	(0.006)	(0.001)
Plant	0.005	0.006	-0.006	-0.005	0.002*
	(0.006)	(0.008)	(0.010)	(0.005)	(0.001)
Harvest	0.008	-0.0004	0.012	-0.010*	-0.004***
	(0.007)	(0.009)	(0.011)	(0.005)	(0.001)
Constant	2.048***	4.827***	3.887***	1.330***	-0.355***
	(0.610)	(0.825)	(1.047)	(0.490)	(0.100)

Note: Standard Errors are in parenthesis with *, ** and ***denoting significance at the 10%, 5% and 1% level, respectively. Variables ΔPe, ΔPc, ΔPs, ΔPb, and ΔPp are first differenced logrithm adjusted ethanol, corn, soybean, beef, and poultryprices, respectively.The variable Grow denotes planting, growing, and harvesting seasons. Variables Specorn and Spesoy denote speculation of corn and soybeans, respectively, and lndollar is the logarithm of the adjusted dollar price.

Corn prices are also positively affecting soybean prices indicating the substitution ability in animal feed rations. Of particular interest is that short-run ethanol prices positively affecting beef prices. This relation may reveal the concern of the livestock industry and its supporters regarding the RFS and their request for a waiver based on the speculation that a relaxation would yield lower corn prices and benefit livestock producers and stabilize the livestock markets. By experiencing a link with ethanol prices and the livestock market and believing in ethanol prices affecting the corn market, they believe that ethanol is causing higher corn prices and negatively impacting the livestock industry. However, the results do not support this scenario.

In terms of consumers, in the short-run, no evidence indicates that corn prices are driving up beef prices. It appears beef producers are reluctant to pass the cost onto consumers, which is consistent with the explanation of beef's slow adjustment to the long-run cointegration and is also verified by relatively stable beef prices during the 2012 drought. However in the long run, beef producers may reduce the amount of herds when facing cost pressure due to increased corn prices. This results in increased beef prices, which is indicated by the long-run cointegration (8).

6.3. Exogenous Variables

6.3.1. Drought Effects

The results listed in Table 4indicate that drought has generally a positive impact on prices of corn and soybeans and a negative effect during the harvest season. This reflects the condition that drought normally would shift upward the crop supply curve leading to higher prices, but during the harvest season, a dry spell is favorable for harvesting and prevents crop damage from severe precipitation.

Drought effects have a similar pattern on ethanol prices as on the crop prices. The ethanol industry will face rising input costs and many scale back production when facing drought. For example, the average production of U.S. ethanol fuel was 865 barrels/day for 2012, while it dropped to 817 barrels/day in July and maintained low during the summer season (Renewable Fuel Association, 2013). This decline only occurred in 2012withethanol demand remaining constant, leading to drought induced higher ethanol prices. Supporters for the RFS waiver observe this positive impact of drought on ethanol and crop prices. They combine this with their assumption that ethanol causes higher corn prices, which leads them to conclude reducing the RFS mandate, under drought conditions, will drive corn prices down. Again, the result does not support this conclusion. The drought may cause higher corn and ethanol prices, but the higher corn prices are not due to higher ethanol prices. The ethanol market is not driving the corn market.

6.3.2. Speculation and the U.S. dollar effects

Considering speculation, results indicate the foreign exchange rate coefficient is negative and significant at the 1% level in the ethanol, corn, soybean, and beef price equations. The relative increase in the exchange rate, results in U.S. exports becoming more expensive, which shift the demand for ethanol, corn, soybeans, and beef downward, lowering their prices. In contrast, poultry prices are significant, but positive. This positive relation is difficult to explain. However, over the study period, poultry has experienced a mark shift in export demand, from 7426 million pounds in 2010 to 8162 million pounds in 2012 (USDA, 2011, 2013d). Poultry parts, particularly feet portions exported to Asia have increased significantly, leading to higher prices even with a strong U.S. dollar.

For ethanol, crop, and beef prices, the coefficient for the soybean speculation index is negative and significant at the 1% and 5% level and positive at 5% for poultry. As the speculative pressure from commodity index traders in the soybean futures market increases ethanol, corn, soybean, and beef prices decline and poultry prices rise. In this case, speculation actually reduces grain prices rather than inflating them. The results are consistent with McPhail (2011), which also indicates no inflated speculative price bubbles in the grain market. In contrast, both the corn and soybean speculative index appear to positively influence poultry prices.

7. Conclusions

The 2012 drought reignited the issue of ethanol's production-impacts on crop and livestock prices. The EPA denial of a RFS waiver to decrease the ethanol mandate following the drought is based on the belief current mandates will have minimal impact on corn and livestock prices. Considering the environmental drought and price relations among the crop (corn and soybean), livestock (beef and poultry), and ethanol markets, the empirical results support this belief.

As a first attempt in linking drought impacts on crop, livestock, and biofuel markets, the Drought Monitor index was employed to measure drought intensity. Incorporating this index into a VECM indicates in general drought has a positive impact on crop prices. This result maybe coupled with the long- and short-run results to assess the underlying justification of a RFS waiver. The lack of ethanol prices influencing crop prices in either the long or short run indicates weather related supply disturbances may play a significantly larger role in affecting crop prices than the ethanol market. Corn prices are influencing the livestock market in the long run and the ethanol market in the short run. However, the livestock market speed of adjustment to volatile corn prices is relatively slow.

This slow adjustment to volatile corn prices on the part of the livestock industry and the resulting higher prices of corn and ethanol from a drought are justifications for a RFS waiver. These results coupled with the belief that ethanol is the cause of higher corn prices; leads to concluding a RFS waiver reducing the ethanol mandate will stabilize corn prices and provide the livestock industry relief from volatile input prices. However, the results do not support this belief. Corn prices are influencing short-run ethanol prices, not the reverse, and in the long-run there is no corn/ethanol price cointergration. Thus, the expectation that a reduction in the ethanol mandate will help mitigate the drought's impact on corn prices is not supported by the results.

These results can serve as a foundation for evaluating policies directed toward mitigating any negative market-price volatility. The impact of drought on increasing the volatility of crop and beef prices suggests policies may be warranted toward reducing this short-run price volatility. However, including the RFS waiver that affects the demand for corn may not be as effective as polices directly influencing corn supply. The ability to mitigate an upward shift in the supply of corn from a drought by directly augmenting supply will partially restore market equilibrium with expanded supply and lower prices. In contrast, a policy providing incentives to reduce demand may be slow in yielding the desired effect of reduced demand and associated price. Such supply-policies could take the form of precautionary private and public agricultural commodity buffer stocks, continuous infusion of public sponsored research and outreach, and reducing regional trade restrictions. However, before such policies are implemented, the underlying economic relation of sister markets should be understood. With the RFS waiver policy as an illustration, economic results indicate such a policy would probably not lead to its desired effects.

CHAPTER 4

U.S. ETHANOL AND WORLD HUNGER: IS THERE ANY CONNECTION?

1. Introduction

U.S. ethanol production, encouraged by a range of government subsidies and incentives, has caused a debate whether sustainable bioenergy from food is causing greater food insecurity in developing countries (Wise, 2012a). Expanding U.S. production and consumption of corn-based ethanol, is considered a major biofuel program, which is possibly causing food price inflation. For decades, international markets are a major destination for U.S. agriculture products (Dilivan, 2015). United States exports corn to most of the developing countries, including countries in Southeast Asia, South America, and Africa. Thus, any price volatility, possibly caused from bioenergy, can extend harm globally, particularly in developing countries.

U.S. corn exports comprise one-third of world corn trade, with U.S. exporting 48.7 million metric tons of the total 130.64 million metric tons traded in 2013/2014 (WASDE, 2015). In contrast, corn net-import countries comprise most of the developing world. With increased U.S. corn-ethanol production potentially crowding out exports, it is possible U.S. ethanol production is a major cause of increased global food prices.

Food price volatility harms the well-being of consumers, particularly those in developing countries, whose food expenditure can account for half or more of household income. In 2009, FAO estimated that the 2007-2008 price spike drove the number of undernourished people in the world from 915 million to more than 1 billion, the highest in over 40 years (FAO, 2009). A similar number of people are believed to be pushed into poverty and undernourishment as a result for the recent 2011-2012 price spike. Rising food prices also may have triggered food riots and political unrest (Lagi et al., 2011; Roberts and Tran, 2013a).

However, on a closer examination, not every country is experiencing the same corn price increase with U.S. ethanol expansion. In Bolivia, average yearly real corn price in 2006 is 0.89 boliviano per kilogram, and it decreased to 0.87 boliviano per kilogram in 2012 (GIEWS, 2014). Some countries may benefit while some not. Thus, research should be directed toward determining the individual country effects. The geographic characters of countries are not something that can be changed, thus attention should be focused on the geographically vulnerable countries. If the countries are vulnerable due to inherent reasons, the aid from outside is especially needed for them.

Previous research in this direction suggests it is the volatile import corn price that makes countries suffer from the U.S. ethanol production (Wise, 2012a, b; Actionaid, 2012). However, this may not necessarily be the case. With a U.S. corn price increase affecting the world price， a domestic market will be affected no matter if it is a net importer or not. Thus, empirical evidence deriving inferences on geographically diverse countries is required before any definitive conclusions can be reached. As a first attempt, the objective is to test the underlying hypothesis that U.S. ethanol demand has differential and possibly limited impact on developing countries' corn prices. A review of the literature indicates there is a gap in empirical research addressing this hypothesis. The aim is to fill this literature gap.

Testing this hypothesis will provide an understanding of the mechanisms and consequences of U.S. ethanol demand transmission effect on food prices in developing countries. In particular, the aim is to explore the hypothesis that transmission effects are systematically weaker in countries with specific geographic characteristics (coastal/isolated and African/American countries). For exploring this transmission effect, a recently developed panel SVAR model is utilized and populated with U.S. ethanol demand and corn prices, and corn prices in developing countries. Conventional dynamic panel methods are not appropriate, given they require the dynamics of individual country responses to be identical among all countries. Furthermore, it is important to consider countries are linked cross-sectionally with common global and regional shocks. For addressing these issues in the context of structural identification, a panel SVAR methodology developed in Pedroni (2013) is employed.

Policymakers in developing countries, the U.S. government, and international institutions, aiming at reducing poverty and malnourishment, require the testing of such hypotheses for effective policies. They can then direct policies and programs to those countries most vulnerable to food insecurity. With the U.S. ethanol industry continuing expanding, it is important for policymakers to understand the bioenergy linkages across countries.

At the 2008 G8 summit, it was emphasized that when facing oil shocks, especially vulnerable are small island economies and landlocked countries with higher than average transportation costs (World Bank, 2008). However, a recent literature indicates that although landlocked countries are experiencing a higher volatility, when holding other factors constant, coastal countries are even more affected by a specific shock, such as U.S. ethanol demand (Lukas and Matthias, 2013). Thus, the coastal countries should be paid no less attention when facing the world economic shocks.

In additional to coastal and isolated countries, focus is also on the difference in African and South/Central American countries. Corn constitutes a large share in dietary country consumption in both continents relative to other continents. From a political perspective, African and

American countries belong to different organizational and political groups; the world organizations inevitably consider the continental effect when making any policy.

The results indicate U.S. ethanol demand is not a major determinant of global corn price, however coastal countries may be more susceptible to U.S. ethanol demand than isolated countries. In contrast, U.S corn prices are a major global corn price determinant and the shock spread evenly across the world.

2. Literature

The potentially implications of rising food prices have sparked an extensive literature investigating the global price transmission and potential U.S. ethanol economic role.

2.1 Literature on U.S. ethanol production

The potentially severe implications of rising food prices on the world's poor have sparked an extensive literature looking at the potential economic role played by the US ethanol mandate (Roberts and Tran, 2013a). Studies of U.S. biofuels expansion generally focus on assessing the price impacts of biofuels policies rather than simply biofuel expansion (Wise, 2012a). Abbott et al. (2008) determined biofuel policies were responsible for approximately one-quarter of the increase in global corn prices, the remainder attributable mainly to higher oil prices. Their follow-up study in 2011 suggested that two major drivers of global food prices in the 2010-11 spike were U.S. biofuels (overwhelmingly corn ethanol) and rising Chinese soybean demand (Abbott et al., 2011). Roberts and Schlenker (2013) calculated that the U.S. biofuel mandate caused a 30% increase in the price of agricultural commodities in 2008. They estimated that the mandate resulted in the removal of 5% of the world's caloric production and this reduction in supply was a major contributor to food price.

Al-Riffai et al. (2010) employs a global computable general equilibrium model (CGE) to estimate the impact of EU biofuels policies and show that the model simulations indicate that the effect of EU biofuels policies on food prices will remain very limited. Laborde D. and Valin (2012) used CGE and evaluated indirect land-use changes due to EU biofuels and pointed out critical uncertainties that prevent them from being able to provide a precise figure on the extent of land-use change and associated emissions.

Roberts and Tran (2013b) consider economic impacts of the U.S. ethanol mandate by modeling storage decisions. According to their research, when food demand increases stemming from the U.S. ethanol mandate, the excess demand can be partly fulfilled by existing grain inventories. As a result, the impact of the U.S. ethanol mandate on food prices is small when grain storage is high and price volatility might decrease in the short run.

Taken together , Hausman et al. (2012), Roberts and Schlenker (2013), and Rosegrant (2008), these results suggest that while the effects of the ethanol mandate were considerable, other factors, such as bad weather and above-trend growth in food commodity demand, likely account for most of the world price increase and volatility changes since 2005 (Roberts and Tran, 2013b).

Regarding U.S. ethanol expansion, the existing literature generally employed projected simulations and partial equilibrium modeling and get different results. Studies on the impacts of biofuels on food and fuel have assumed that energy prices are either fixed or determined in competition (deGorter and Just, 2009; Rajagopal et al. 2009). As an example, the Organization for Economic Cooperation and Development (OECD) compared alternative scenarios and concluded that if biofuel production remained at 2007 levels, rather than doubling over the next decade as projected, prices for coarse grains (primarily corn) would be 12% lower in 2017 (OECD, 2008). Hochman et al. (2010) employed a partial equilibrium model and determined if world corn ethanol were not produced, the price of corn would have been 7.26% lower in 2005 and 12.18% lower in 2007 (Hochman et al., 2010).

Baier et al. (2009) study employed an IFPRI model to estimate the biofuel contribution to 2006-2008 food price increases. They concluded that worldwide biofuel production had pushed up corn prices by 27% and that U.S. biofuels production increased corn prices by more than 22%. In terms of global food prices, they found that just over 12% of the rise in the IMF's food price index could be attributed to biofuels, but that 60% of that contribution came from U.S. biofuels production.

Babcock (2011) employed partial-equilibrium modeling and made a comparison of the new equilibrium prices and quantities with what actually occurred, the results revealed that the impacts of these subsidies on crop prices were quite modest, thus implied that ethanol subsidies were not the major driver of higher commodity prices including maize.

Using Babcock's (2011) simulated results, Wise (2012b) further calculated net corn importing countries' loss due to U.S. ethanol expansion. Altogether, the ethanol-related losses totaled $11.6 billion for all net corn importing countries. And developing countries incurred more than half the costs. Growmark (2013) concluded a larger effect on corn markets than U.S. ethanol production is that of investment flows channeled into the corn market by investors/speculators, the speculation demand trumps ethanol demand. Lagi et al. (2012) calculated that from 2003-4 to 2010-11, U.S. ethanol expansion cost Mexico about $3.2 billion, while financial speculation added another $1.4 billion to the country's seven-year corn import bill.

Overall, the conclusions are far from definitive. Considering the methodology, the above analysis are generally based on large macroeconomic economic systems models employing predetermined elasticities and parameters (Condon et al., 2013; Berry, S., 2011). Such modeling makes it challenging to distinguish the short- and long-run impacts and specific marketing channels are not clearly delineated. Also, specific micro-channels associated with food and biofuel markets are not clearly defined or quantified.

2.2 Literature on food price transmission

Regarding price transmission across under developed countries, as summarized by Minot (2011), a large number of studies examine the degree of price transmission among markets within a country, however fewer studies examine the transmission across countries (see Abdulai, 2000 for Ghana; Lutz et al., 2006 for Benin; Negassa and Myers, 2007 for Ethiopia for example). Quiroz and Soto (1995) and Mundlak and Larson (1992) employed similar data but different models and resulted differently: Mundlak and Larson found an average of 95% price transmission; Quiroz and Soto (1995) found no relationship between domestic and international prices for 30 of the 78 countries examined, and even in countries with a relationship, the convergence was generally very slow.

Minot (2011) analyzed the relationship between domestic and international prices in the longer term for 62 staple food prices in 9 African countries over five to ten years using an error correction model (one domestic price and one international price each time) to estimate the degree of price transmission. The results indicate a long-term relationship with world prices in only 13 of the 62 African food prices, and the global food crisis was unusual in influencing African food prices, probably because of the size of the increase and the fact that it coincided with oil price increases. African countries could reduce vulnerability to fluctuations in world food prices by staple food self-sufficiency.

Conforti (2004) provides evidence on price transmission in a number of agricultural markets. The work is based on a price database collected from various sources in 16 countries across

African, Asian, and South American continents. Employing the same method of Minot (2011), results indicated: 1. there is a geographical regularity. Results for African countries generally tend to show a lower degree of price transmission compared to that of other countries. Physical barriers, infrastructural gaps, together with remoteness and limited market sizes, are all elements to be further investigated in order to gain a wider understanding of the specific cases; 2. geographical and infrastructural distances are likely to imply more substantive stationary transaction costs and transmission between the domestic and the border prices is fairly incomplete in many countries in which the domestic markets appears to be fairly integrated; 3. a high and fast transmission is found in cereals including maize; 4in the long run an interventionist policy environment cannot prevent domestic prices from following world price trends and signals, and/or that policymakers were taking into account world market trends in managing of domestic markets.

By using generalized method of moment, Lukas and Matthias (2013) employed panel data with a maximum of 12 years per unit yearly data between 2000 and 2010 selected from 50 plus countries and found that landlocked countries experience less variability in grain prices, while African countries have more volatile prices than countries on other continents. Besides, demand shocks and international price volatility have a great impact on domestic volatility. Further, trade policy restrictions seem to fail in limiting volatility transmission from international. They also found that although volatility of maize price is higher in landlocked countries than in coastal countries, when holding other factors constant, landlocked character significantly reduces the maize volatility. A possible explanation is that, naturally, landlocked countries cannot rely on food imports, as much as coastal countries can do, and thus are less exposed to international price shocks (Lukas and Matthias, 2013). However, the research has its own caveats. First, all coefficients indicate on-average effects. Thus, findings may not apply for a particular country but are only valid on average. Second, it is not still suffered from endogenous critics.

In sum, empirical research on food price transmission across countries is scarce, and the conclusion regarding which countries tend to be more vulnerable to the world market is far from established.

Regarding the methodology, except the only paper employing the generalized method of moments, the mostly used is time series modeling. However, employing a standard time series analysis on each country for estimating individual country effects poses two empirical challenges (Mishra et al., 2014). First, many countries have a relatively short spans of data available. For such countries, a standard time series analysis would not be reliable. Second, the data from many of the countries are fairly noisy, so even when a span of data is available, a conventional time series analysis for any one country may not be reliable. An alternative is to expand the panel dimension of the data to increase the reliability of the inferences (Mishra et al., 2014).

3. Econometric methodology

Considering the caveats of scenario simulation and partial/general equilibrium models, and the limitation of generalized method of moments and standard time series analysis on each country, an alternative time series model is employed. Specifically, a structural vector autoregression (SVAR) model is adopted. However, a time series model poses its own challenges. The developing country corn prices are likely interdependent and respond to common external shocks, which are not directly observable. In order to exploit the panel dimension, this form of cross sectional dependence should be considered for deriving inferences regarding the distribution of country responses. Furthermore, if the dynamics are potentially heterogeneous among countries, it should be explicitly taken into account. Not addressing the heterogeneity and instead treating the country dynamics as homogenous members of a pooled panel, risks inconsistent estimation and inference (Pesaran and Smith, 1995; Mishra et al. 2014).

There is limited literature on panel SVAR and the methodology developed requires specific assumptions about the timing of information flows and of responses. This would be hard to justify across a group of very diverse economies. As an example, the speed with which U.S. ethanol demand shocks affect local market prices are likely to differ by country. Furthermore, for estimation, the potential country linkage cross-sectionally via common global and regional shocks should be addressed (Mishra et al., 2014).

A heterogeneous panel SVAR methodology, developed by Pedroni (2013), is the appropriate method for uncovering the properties of the underlying structural dynamics. This is particularly the case when the panels are relatively short. Even the fairly small panels with 30 time periods and 20 cross sectional units do fairly well for responses to shocks by comparing it with panels with 100 to 200 time periods and 30 cross sections. Another advantage is the ability to consider the different lag periods for each individual country. The method allows loops over each country member and applies information criteria separately for each country. The approach exploits orthoganalities associated with structural VAR identification schemes. The result is a sample distribution of heterogeneous country responses to structural shocks, which accounts for both the dynamic heterogeneity as well as the cross sectional dependency. For example, $Z_{it} = (P_{it}, C_{it}, PC_{it})'$, with dimensions i=1,..,N,t=1,…,ti, denote our unbalanced panel, which have been demeaned to eliminate country specific fixed effects.

The first step is to compute the cross sectional averages of the differenced data, namely $\varepsilon_{\mathrm{it}} = \Lambda_i \overline{\varepsilon_t} + \tilde{\varepsilon}_{it}$, where $\varepsilon_{\mathrm{it}}$ are the composite shocks, $\overline{\varepsilon_t}$ are the common shocks, $\tilde{\varepsilon}_{it}$ are the idiosyncratic, country specific shocks. Λ_i is a diagonal matrix of the country specific loadings, which reflect the relative importance of the common shocks for a particular country. Specifically, we consider the orthogonal structural shocks to be decomposed into orthogonal common and idiosyncratic components. For a detailed discussion refer to Pedroni (2013). Applying this approach, the effects of U.S. ethanol and corn price shocks on developing countries' corn prices are estimated. Following Mishra et al. (2014), a Structural VAR model with restrictions is employed. After a panel unit root test, the long-run structural form of the system can therefore be expressed as:

$$\begin{bmatrix} Q_t \\ P_t \\ PC_t \end{bmatrix} = A(1) \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} , \quad (9)$$

where Q and P denote U.S. ethanol demand and first differenced log transformed of real corn price, respectively, in time t, and PC is the first differenced log transformed real price of corn in a developing country. Realization ε1t is the unexpected shock to output, Q, which is uncorrelated with ε2t and ε3t, the unexpected shocks to the U.S. domestic corn price and price of corn in the developing countries, respectively. Examples are a demand shock resulting from a policy change in the Renewable Fuel Ethanol mandate or a shock to corn prices due to a U.S. Midwest drought.

The matrix A(1) is 3X3 containing the long-run impulse responses, with zero upper diagonal elements. Equation (9) models U.S. ethanol demand as only affected by its own innovation. U.S. ethanol demand is currently supported by a federal ethanol mandate, which dictates the market level of ethanol demand. Thus, in contrast to a free market, ethanol is not based on the input price (the corn price). However, Equation (9) does model U.S. corn prices affected by innovations in U.S. ethanol demand. With approximately 40% of U.S. corn funneling into refining ethanol, at least in the short run ethanol would impact U.S. corn prices (Qiu,et al., 2012; Hao, et al., 2015) . Further, Equation (9) models the corn prices in developing countries affected by both the innovations of U.S. ethanol demand and U.S. corn prices. The United States is the leading world producer and exporter of ethanol. Its major developing country ethanol markets are Brazil, Mexico, Peru, and the Philippines. This exporting of ethanol is expected to particularly affect a country's corn price if it has an ethanol industry competing with imports from the United States. The United States is a major world corn producer with 11% of its production destined for export. It is the leading corn exporter accounting for approximately 40% of world corn exports (U.S. Grains, 2015). U.S. corn prices will likely affect an developing country's corn price but not the reverse.

The U.S. ethanol demand is employed as the indicator for U.S. ethanol expansion. It is directly subject to U.S. government ethanol policy, so the innovation could capture ethanol market sensitively to policy shocks. An example is the Renewable Fuel Ethanol mandate, which requires U.S. transportation fuel contain a minimum volume of renewable fuels. Any change in the mandate, ethanol demand will change instantaneously, with a lag in ethanol production.

4. Data

The choice of the country panel is guided by the desire to limit attention to developing countries with availability of reliable monthly data on corn prices. This yields monthly real price series of corn adjusted by local inflation rates for 34 countries from beginning of 2009 through 2013, Table A.1 (FAO GIEWS, 2014). U.S. monthly corn prices are from USDA and ethanol production is from the Energy Information Administration (EIA, 2014; USDA, 2014).

Table 1 presents the monthly adjusted corn price series summary statistics for each category. Developing countries, which are defined according to the World Bank, are further categorized as coastal or isolated countries and African or American countries. A country is defined as coastal if it has a seaport and borders with another country. If not, then it is defined as an isolated country with no seaport or an island separated from the major trading lanes.

Table 9. Summary statistics for monthly corn real price series, Jan 2009 to Dec 2013

Corn price ($/kg)	United States	Total developing countries	Coastal Countries	Isolated Countries	African Countries	American Countries
Mean	0.54	0.30	0.30	0.31	0.28	0.36
Minimum	0.33	0.04	0.04	0.06	0.06	0.07
Maximum	0.76	7.03	1.64	7.03	7.03	1.63
Standard Deviation	0.15	0.34	0.24	0.51	0.41	0.29
Coefficient of Variation (Std/Mean)	0.28	1.13	0.80	1.65	1.46	0.81
Skewness	−0.16	10.24	2.90	9.72	12.16	2.23
Kurtosis	1.44	163.52	12.60	106.94	170.58	7.77
Unit root test statistics after the first differenced log transformation	−5.89*	−19.78*	−17.27*	−9.65*	−5.12*	−12.64*
Number of	–	34	25	9	15	14

Note: Augmented Dickey fuller test is employed to test U.S. corn price and the Z statistics value is reported. Harris-Tzavalis unit root test, Levin-Lin-Chu unit root test, Breitung unit-root test, and Im-Pesara-Shin unit root test are all employed, and the results all indicate unit root test are significantly rejected at the 1% level, and only adjusted t statistics value of the LLC unit root test reported. * denotes 1% significance level, indicating for all the transformed price variables the unit root hypothesis is significantly rejected.

Comparing the U.S. with the developing countries, the mean of the U.S. corn price is relatively higher and associated with the lowest coefficients of variation, 0.28. This indicates greater stability in the U.S. food market relative to other markets. Skewness indicates that U.S. corn prices exhibit a slight left skewness, which indicates a longer left tail distribution. In contrast, developing countries exhibit right-tail skewness. The kurtosis for less developed countries is much higher than the U.S. prices, which indicates that more of the variance is the result of infrequent extreme deviation as opposed to U.S. corn prices (platykuric distribution).

The mean value of isolated countries and coastal countries are significantly different from each at only the 52% level, which supports the Law of One Price. However given the price swings in corn, the coefficient of variation in the isolated countries, 1.65, is much higher than coastal countries, 0.80, which is consistent with existing studies by Minot (2012) and Lukas and Matthias (2013). Skewness and kurtosis of isolated countries indicates a longer right tail on a distribution figure with relatively thicker distribution tails compared to coastal prices.

The -American countries generally have higher corn prices relative to African countries with a lower volatility. The reason could be third degree price discrimination, where in response to competition the elasticity of demand is more elastic in Africa. The higher volatility of corn prices in African countries is possibly attributable to the political and economic turmoil the countries have experienced. Food has in the past been used as a weapon in civil and religious conflicts. The confiscation and reallocation of large-scale commercial farms has disrupted maize production, while hyperinflation and occasional disturbances have discouraged investment.

The tests, also listed in Table 1, reject the presence of a unit root at the 1% significance level, when the price data are first differenced and logarithm transformed with the level U.S. ethanol demand. These results indicate a Structural VAR model is appropriate to employ.

5. Empirical results

Results provide empirical tests for understanding the impact of U.S. ethanol production transmission on food prices in developing countries. Impulse response functions are illustrated in Figures 1 through 7. Three spatial quartile lines are represented in the figures. The median, 25%, and 75% lines represent the median of the responses among the developing countries, 25% of the developing country responses below the line, and 75% falling below, respectively.

As indicated in Figure 1a, for all the developing countries, a U.S. corn price shock on ethanol demand at first yields a marked decline in ethanol demand, but it quickly rebounds and after seven months any U.S. corn price shock on ethanol demand is dissipated. This supports previous research addressing the long-run corn/ethanol relation (Qiu, et al., 2012). A U.S. ethanol demand shock on itself is a mirror image of the corn price shock on U.S. ethanol demand, with it likewise dissipating in seven months (Figure 1b). However, the shock has a long-run persistence. The 25% and 75% quartiles are very tightly bounded around the median quartile, indicating the impulse responses on U.S. ethanol demand and corn prices do not very widely across developing countries.

The impact of U.S. corn prices from its own shock, Figure 2a, indicates a positive shock with persistence. Similar effects occur for an ethanol demand shock on U.S. corn prices (Figure 2b). Here the quartiles are not as tight but still within the 95% confidence bands.

The impacts of U.S. ethanol demand or corn price shocks on developing countries' corn prices are markedly different from the U.S. corn price impacts, Figure 3. As illustrated in Figure 3a, a U.S. corn price shock will increase corn prices in developing countries. This increase is also persistent. In contrast, an ethanol demand shock has mixed results. Approximately 50% of the countries will experience no increase or a decline in their prices.

For further investigation of U.S. ethanol demand and corn price shocks on developing countries' corn prices, the countries were categorized into different marketing potential. As indicated in Figure 4, coastal countries have a more volatile corn price response from a U.S. corn price shock relative to the isolated countries. In spite of technological improvements in transport, landlocked developing countries continue to face structural challenges to accessing world markets (Faya et al., 2004). As a result, these countries often lag behind their maritime neighbors in overall development and external trade. Weak infrastructure imposes direct costs on trade passing through a transit country, and thus, limits the ability of a landlocked country to access global markets.

The market isolation appears to retard competitive forces, which moderates any global price volatility. As illustrated in Figure 5a, U.S. ethanol demand shocks result in approximately 75% of coastal countries experiencing a positive increase in their corn prices, while the opposite occurs for the isolated countries, as indicated in Figure 5a. Isolation from global markets can have its benefits when there is a global shock such as increased U.S. ethanol demand.

These differences in U.S. ethanol demand shocks versus corn price shocks in isolated countries underscores the difference in their market linkages. A direct U.S. corn price shock appears to result in higher developing country corn prices, with possible less volatility for those countries relatively isolated from world markets, isolated countries. In contrast, for a U.S. ethanol demand shock, there appears to be some slippage in the market. Although there is a corn price response to this ethanol demand shock, the price response is not as large relative to a U.S. corn price shock. The elasticity of a change in corn prices to a change in ethanol demand appears to be more inelastic relative to U.S. corn prices. If the ethanol supply response to this demand shock is limited, then the demand shock will have mainly resulted in increased ethanol prices with limited impact on corn prices. This would be the case if ethanol refineries were operating at near full capacity, which limits their supply response.

In terms of continental effects, Figures 6 and 7 compare different impacts from the United States' shocks in American versus African countries. American and African countries experience similar volatility in their corn prices to a U.S. corn price shock (Figure 6). Particularly in the long run, a U.S. corn price shock appears evenly spread throughout the developed countries. Both country groups response become stable in the long run. However, in the short-run, the initial response of African countries are much higher than the response in American countries, and the stabilizing time of African countries is longer than American countries. The reason could be American countries tend to have a higher market negotiation power and could adjust to the market. In the Southern Hemisphere, the planting and harvesting seasons are opposite from U.S. planting season. The farmers could use the advantage to adjust their own production after discovering the size of the U.S. crop, thereby providing a quick, market-oriented supply response to a U.S. shortfall (USDA, 2015). However, in the long run, U.S. corn still dominates the world corn market and following the Law of One Price, the American market is affected.

In terms of an ethanol demand shock, African countries may have a slightly lower volatility in their corn prices from a U.S. ethanol demand shock (Figure 7). This indicates the particular global location of a country may play at least a short-run role along with its access to world trade.

6. Conclusions and policy implications

As the first literature assessing the impacts on U.S. and global food market and biofuel markets, the results are keys to analyze the adequacy and efficiency of the observed government responses as well as suggesting reasonable policies and food aid options for the future. With ethanol production increasing, it is imperative to answer the above research questions.

The results show that U.S. corn prices do positively affect corn prices in most of the developing countries; while we cannot find a similar effect of U.S. ethanol demand, thus indicating the U.S. ethanol doesn't affect corn markets in all countries.

In contrast to the findings in the bulk of the literature analyzing the U.S, ethanol is aggravating the effect on hunger issues in other countries, the bifurcation mechanisms between the ethanol demand and corn prices showing that one overarching aiding policy and program may not be effective in promoting hunger issues efficiently. Specifically, if there are no long-run causations between U.S. ethanol demand and specific countries' commodity market, then an over-arching arguing policies targeting on ethanol production may not be required.

Consistent with the existing literature, our results show that although landlocked countries are experiencing a higher volatility, when holding other factors constant, coastal countries are even more susceptible to a world economic shock, such as U.S. ethanol demand. Thus, the coastal countries should be paid no less attention when facing the world economic shocks.

The U.S. government, concerned governments, and international institutions aiming at reducing poverty and malnourishment in developing countries, including FAO, USAID, etc. can take a precaution of the possible consequences of ethanol production in U.S. and target the most vulnerable countries and make food aid. Policies, such as food aid and agricultural commodity buffers, designed to blunt these price spikes could be developed and implemented accordingly. Trade rules negotiated at the World Trade Organization could offer hope on key issues affecting the most vulnerable. Limits on subsidies in developed countries, expanded market access for developing country goods and protection for the poorest farmers are sorely needed outcomes of any such process. Farmers in developing countries need improved incentives to invest to produce the food we need. Until recently, multilateral talks focused almost exclusively on issues that were the product of an era of historically stable and declining food prices. Trade talks need to reflect changing realities, such as countries limiting exports, biofuel policies tying food to fuel and the increasingly risky nature of agriculture. Governments need to address these challenges collectively. Unpredictable climatic conditions and volatile prices may require more targeted policies to ensure that enough food is accessible and available for all (Ricardo Meléndez-Ortiz , foreword, 2011).

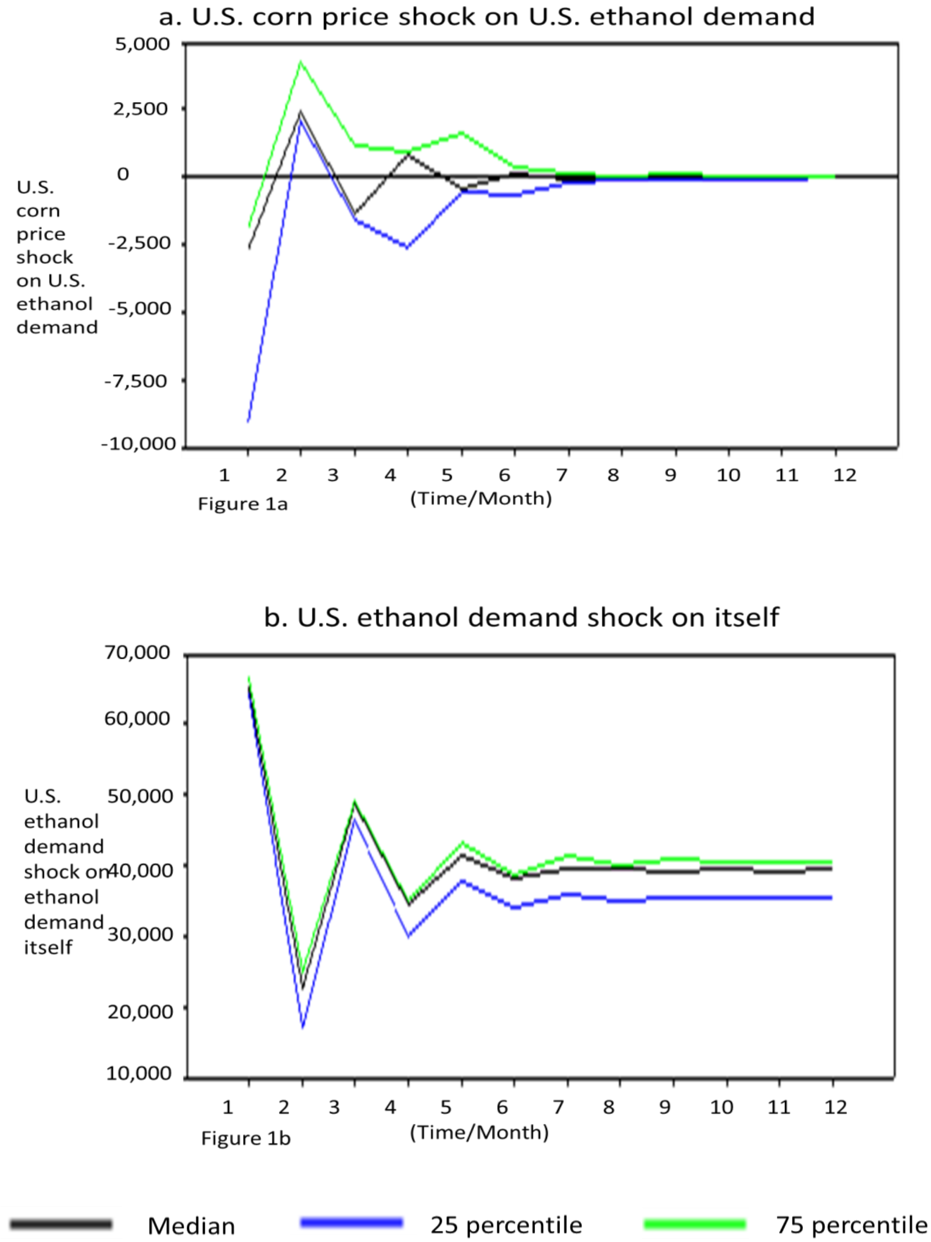
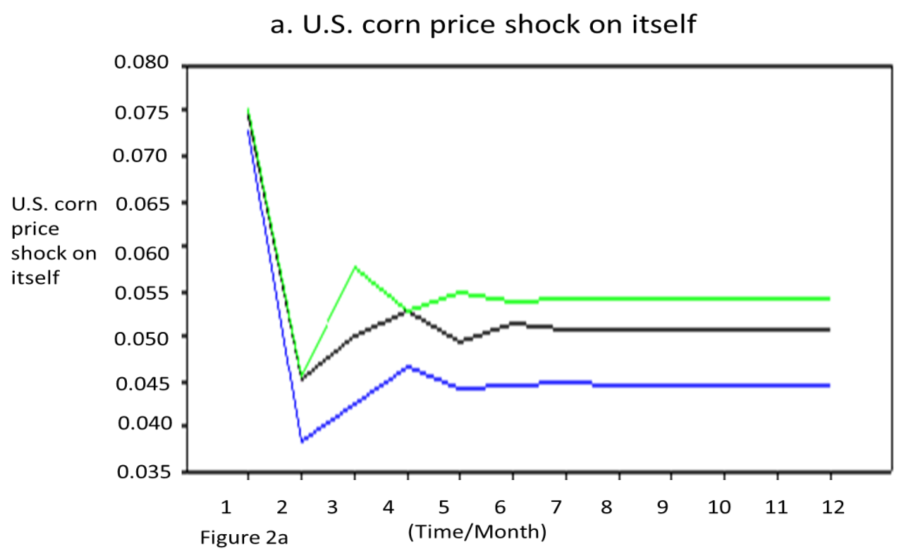


Figure 1. U.S. ethanol demand response to U.S. corn price shock (a) and U.S. corn price to U.S. ethanol demand shock (b)



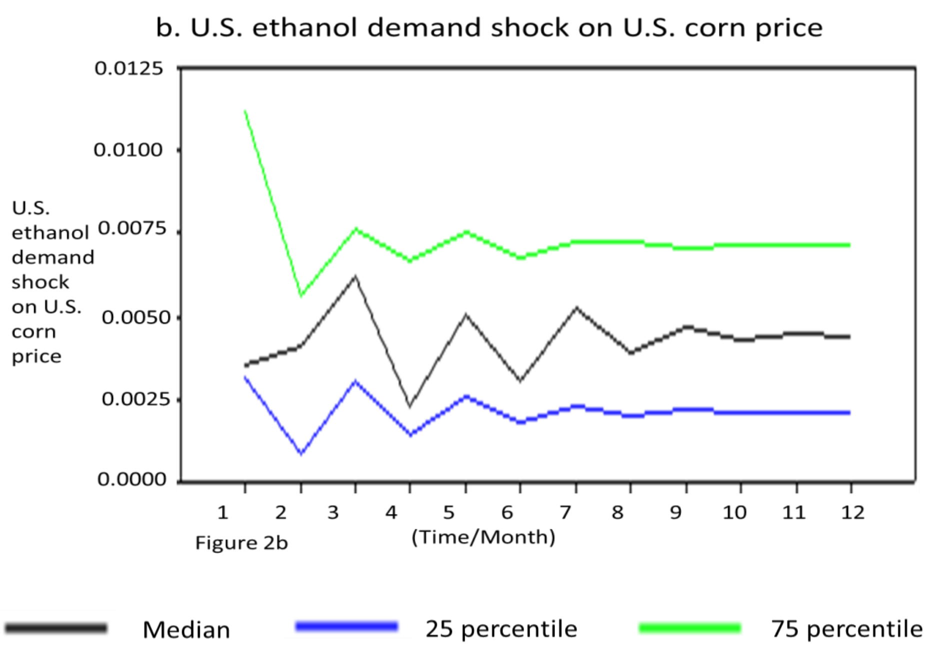


Figure 2. U.S. corn price's response to U.S. corn price shock (a) and U.S. ethanol demand shock (b)

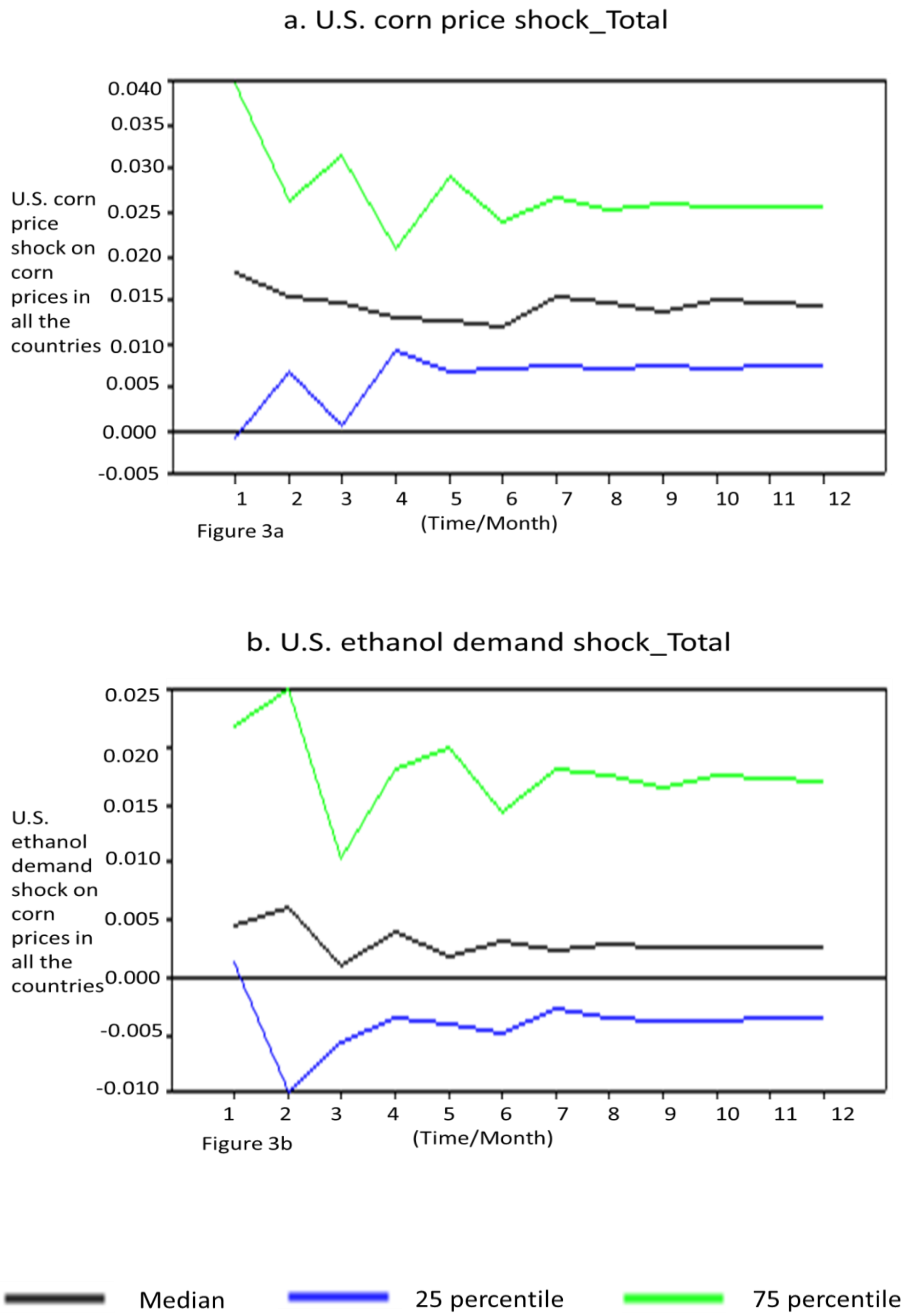


Figure 3. Developing countries' corn prices responses to U.S. corn price shock (a) and ethanol demand shock (b)

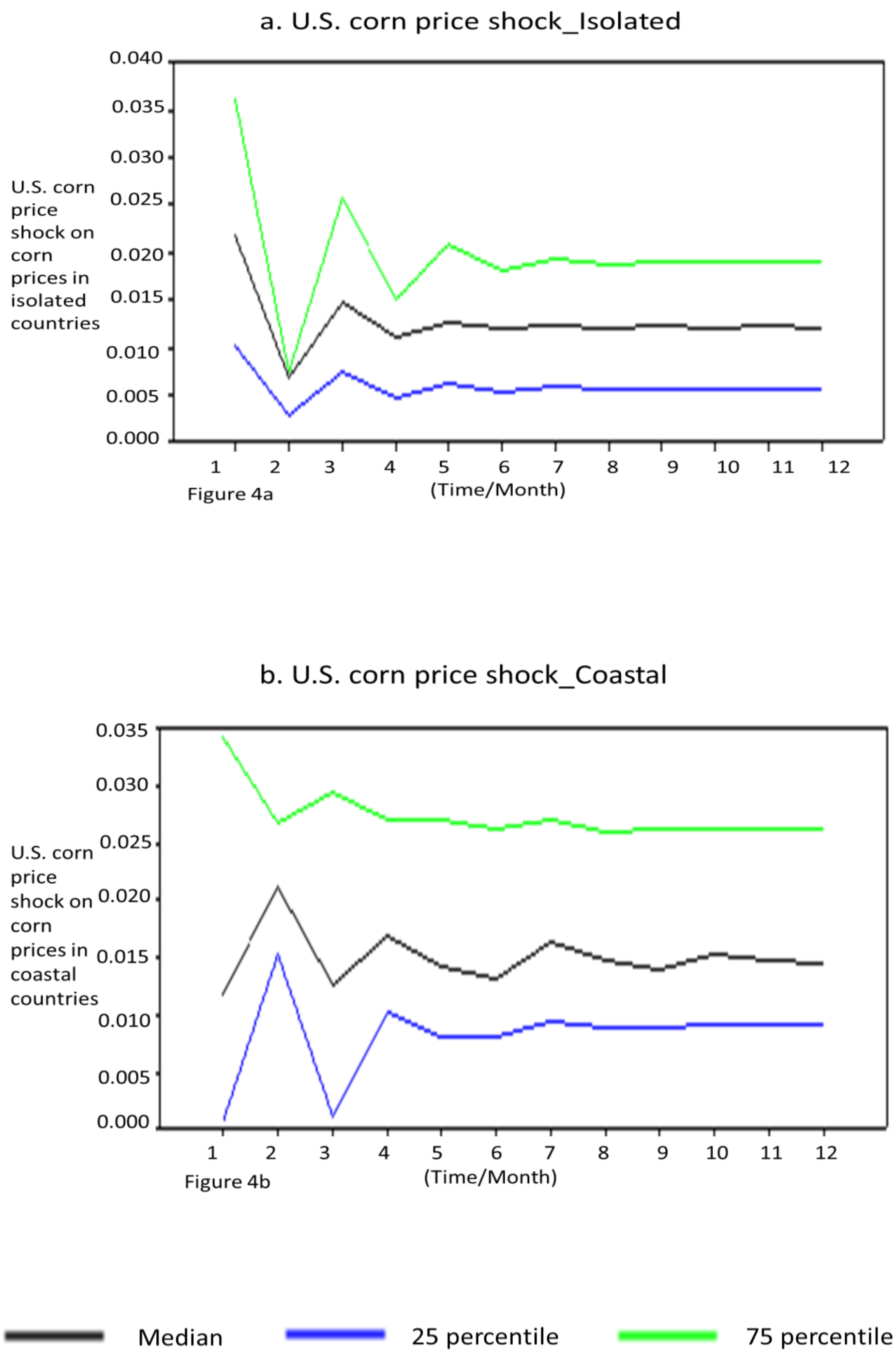


Figure 4. Isolated countries' (a) and coastal countries' (b) corn prices response to U.S. corn price shock.

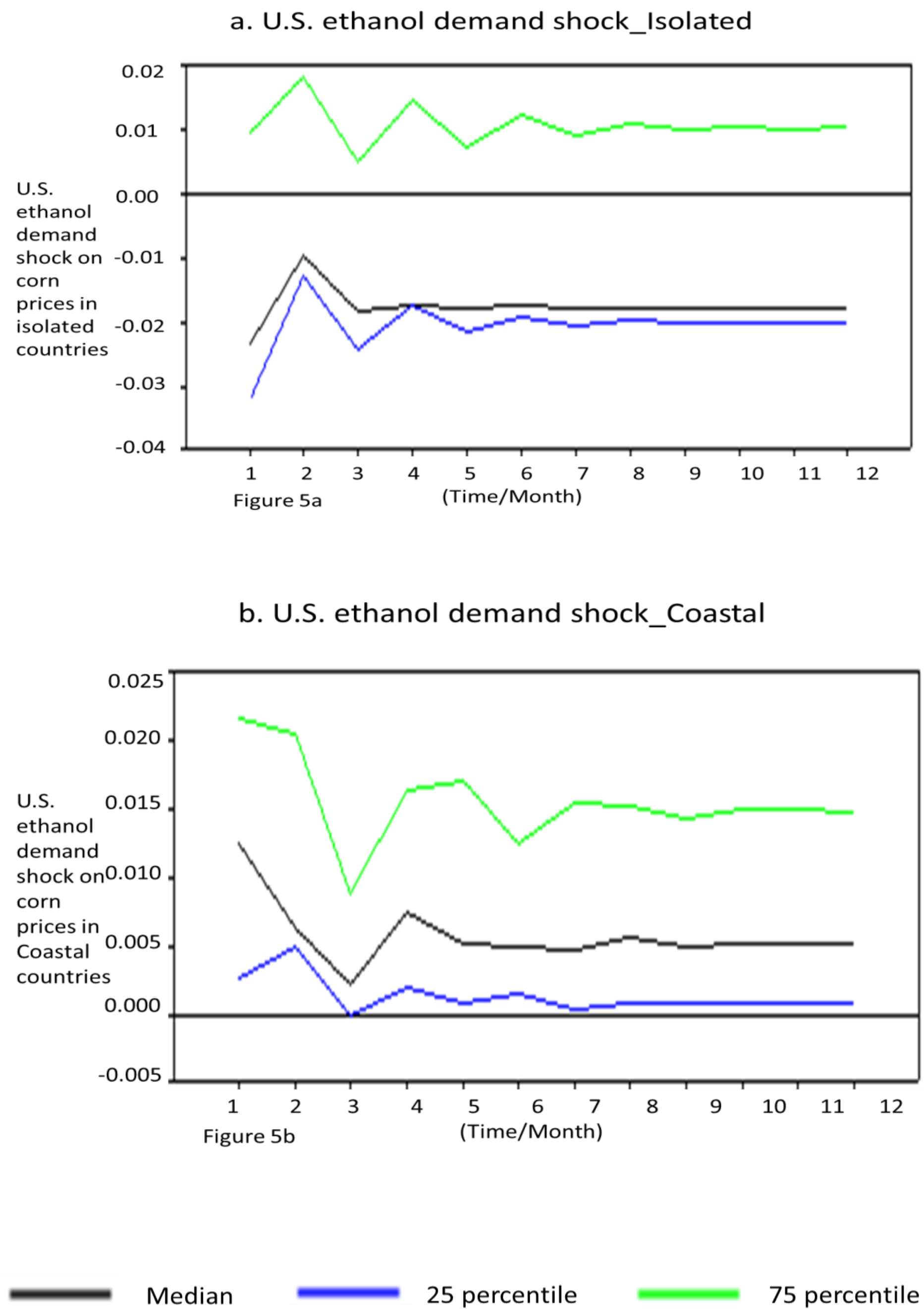


Figure 5. Isolated countries' (a) and coastal countries' (b) corn prices response to U.S. ethanol demand shock.

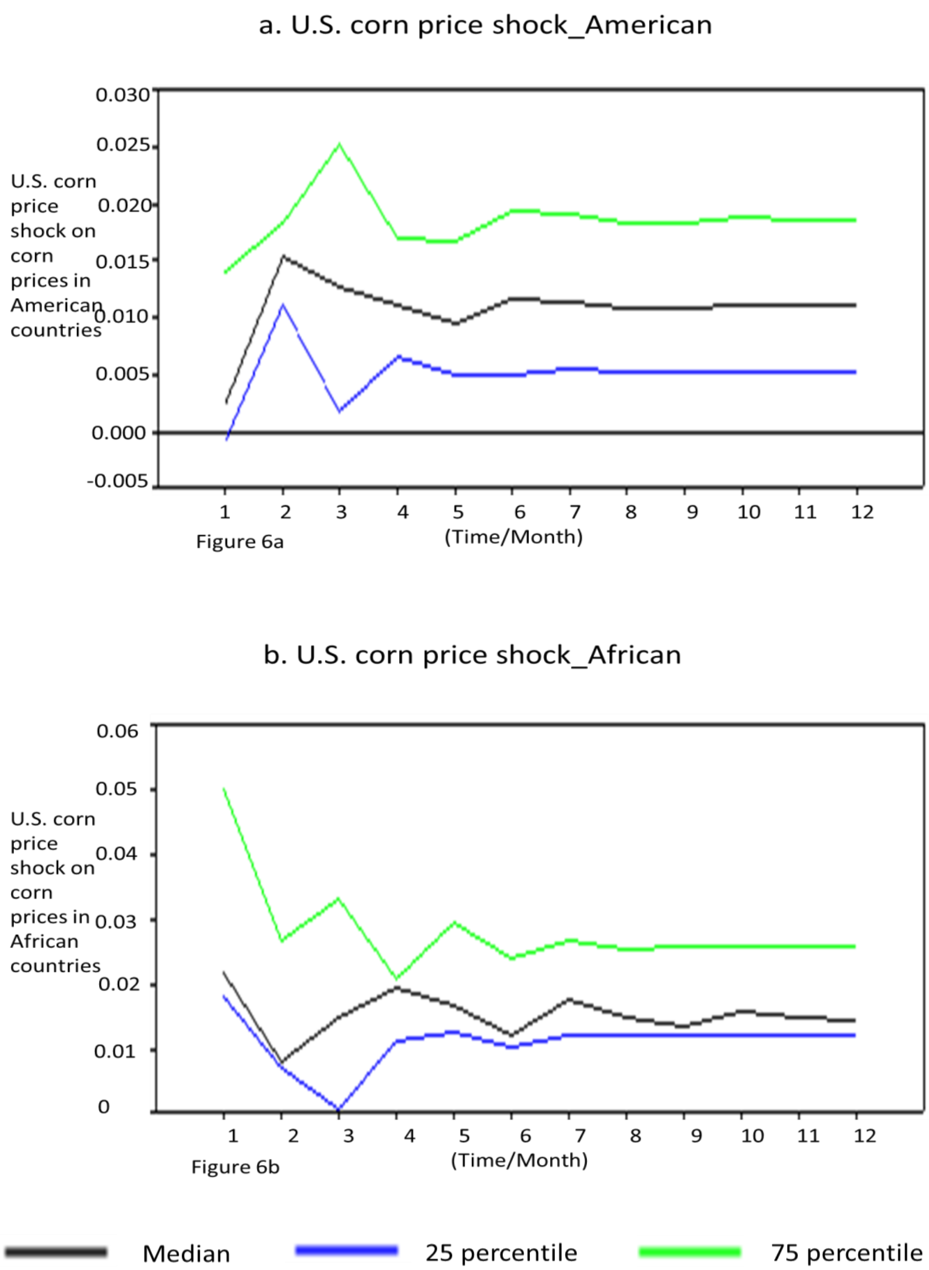


Figure 6. American countries' (a) and African countries' corn prices responses to U.S. corn price shock.

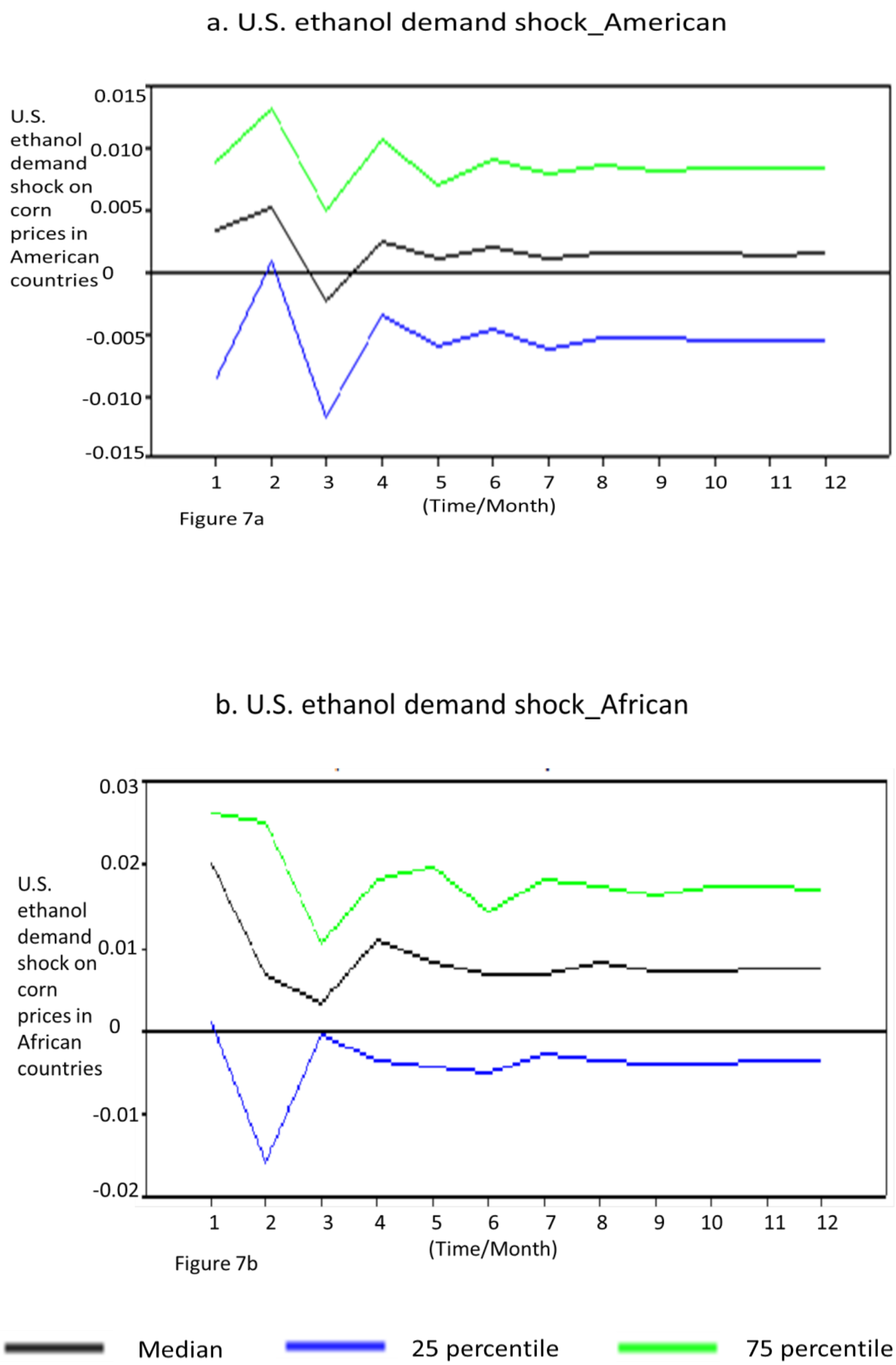


Figure 7. American countries' (a) and African countries' (b) corn price responses to a U.S. ethanol demand shock.

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Appendix: Table A.1 Country list

Country	Continent	Type[a]
Argentine Republic	South America	Coast
Democratic Republic of Congo	Africa	Isolated
Dominican Republic	North America	Coast
Federal Republic of Ethiopia	Africa	Isolated
Federal Republic of Nigeria	Africa	Coast
Federative Republic of Brazil	South America	Coast
Kingdom of Thailand	Asia	Coast
Plurinational State of Bolivia	South America	Isolated
Republic of Cabo Verde	Island	Isolated
Republic of Cameroon	Africa	Coast
Republic of Chad	Africa	Isolated
Republic of Chile	South America	Coast
Republic of Colombia	South America	Coast
Republic of Costa Rica	Central America	Coast
Republic of Ghana	Africa	Coast
Republic of Guatemala	Central America	Coast
Republic of Haiti	North America	Coast
Republic of Honduras	Central America	Coast
Republic of Kenya	Africa	Coast
Republic of Moldova	Europe	Isolated
Republic of Mozambique	Africa	Coast
Republic of Nicaragua	Central America	Coast
Republic of Niger	Africa	Isolated
Republic of Panama	South America	Coast
Republic of Peru	South America	Coast
Republic of Rwanda	Africa	Isolated
Republic of South Africa	Africa	Coast
Republic of the Philippines	Asia	Coast
Republic of Zambia	African	Isolated
Russian Federation	Asia/Europe	Coast
Togolese Republic	Africa	Coast
Ukraine	Europe	Coast
United Mexican States	North America	Coast
United Republic of Tanzania	Africa	Coast

[a] A country is defined as coastal if it has a seaport and borders with another country. Thus, Cabo Verde, an island country is not defined as a coastal country, but an isolated country.