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The Ethanol Mandate and Corn Price Volatility*

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ABSTRACT

Food price shocks can have substantial welfare implications, particularly in the world's low income regions. A number of previous studies has shown that the United States ethanol mandate has increased average corn price levels. We provide suggestive evidence that the mandate has also increased corn price volatility. Identification relies upon a series of falsification tests. Our results suggest that the ethanol mandate has increased the likelihood of very high price levels by even more than previously thought.

Keywords: Ethanol; biofuels; food price shocks; food security.

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1 Introduction

Food price shocks have repeatedly lead to riots and civil unrest over recent years (CNN (2008) and Keating (2011)). We ask whether the U.S. ethanol mandate may have contributed to the severity of food price shocks by increasing the volatility of corn prices.

The Renewable Fuels Standard (RFS) and subsequent RFS 2 mandate biofuel use in the U.S. The mandate, which went into effect in 2006, has increased over time to its current level of 15 billion gallons per year, which is more than ten percent of U.S. gasoline consumption. [1] This ethanol is overwhelmingly made from corn. Over forty percent of the U.S. corn crop is now used to produce ethanol (USDA (2015)). A number of prior studies have shown that this dramatic increase in corn demand has raised average corn prices (Fortenbery and Park (2008), Mitchell (2008), Roberts and Schlenker (2009), and Roberts and Schlenker (2010)).

This paper asks whether the U.S. corn ethanol mandate increased grain prices volatility. We pay a particular attention to the fact that inelastic supply and demand is a generally appreciated source of high price volatility.[2] This study differs from other research that focus primarily on (1) the relationship between the policy and gasoline price or gasoline price volatility; or (2) the relationship between the mandate and food prices level. We use a reduced form econometric approach based on a series of falsification tests and provide evidence that one additional billion gallons of the ethanol mandate has indeed increased corn price volatility by approximately 2.88 percent.

[1] The RFS and RFS2 actually specified both a total mandated quantity and specific mandates for a variety of advanced biofuels. While the difference could be met with a variety of fuels, in practice corn-based ethanol is the cheapest and so the difference amounts to a corn ethanol mandate.

[2] See, for example, Borenstein (2002), Hertel and Beckman (2011), and Regnier (2007).

The rest of this paper consists of following sections. Section 2 reviews the literature on the impact of the ethanol mandate on corn prices. Section 3 models how an ethanol consumption mandate could increase corn price volatility. Section 4 describes our data, while section 5 describes our econometric approach. Results are presented in section 6, while section 7 concludes.

2 Literature Review

Ethanol is made mainly from corn in the United States and used as an component of gasoline.[3] It means that markets for ethanol, corn (and perhaps other crops), and fuels can be correlated to each other because of the ethanol mandate which connect those markets. A large number of literature has conducted economic analysis on verifying relationships among those markets.

The influence of the ethanol mandate on fuel prices is a matter of ongoing research. Theoretical models show that the magnitude and direction of effects depend on the supply elasticities (De Gorter and Just (2009)). Econometrically, Du and Hayes (2009) argue that the increase in ethanol production lowered wholesale gasoline prices substantially although the magnitude varies over region—the impact is the largest in Midwest, the major corn producing area in the United States. However, Knittel and Smith (2012) argue that ethanol production may not be a viable factor that influences gas prices. They also point out that even if there exists an impact so that recent low refining margin is due to ethanol production, the impact is not viable in the long run because low entry barrier will accommodate new agents to the industry. Maniloff (2013) is also skeptical about ethanol's ability to substantially lower US gas price volatility or isolate domestic gasoline prices from oil shocks. Maniloff also mentions that under a binding mandate gasoline price volatility can be lower but it accompanies a significant cost. Vedenov et al.

[3]Fuel is technically known as ”gasahol” when it contains ethanol. We use ”gasoline” for familiarity.

(2006) examine the opposite directional causality. They conclude that when gasoline prices are volatile, refiners in a competitive market will adopt more alternative fuels with lower price volatility as substitutes which will ensure them the portfolio effect.

The impact of ethanol production on corn prices is more robust. While the impacts of biofuels policies on food prices can vary based on factors such as the degree to which biofuel feedstocks compete for resources with food products, studies have consistently found that the ethanol mandate has raised corn prices (Zilberman et al. (2012)). Typical estimates are that corn prices would be a third to a fifth lower absent the mandate (Carter et al. (2013), Roberts and Schlenker (2010), and Wright (2014)).

However, few researchers focus on the direct relationship between mandate and corn prices volatility. McPhail and Babcock (2012) develop a simulation model and find that current ethanol policies increase price volatilities of both corn and gasoline by decreasing price elasticities of demand for both commodities. Similarly Wright (2011) attributes recent price shocks to a variety of supply, demand, and inventory factors of which the biofuel mandate was one. To our knowledge, this paper is the first to complement these theoretical and simulation studies with econometric evidence.

Bellemare (2015) shows that high food price levels are the key determinants of civil unrest. However, we should still consider volatility because an increase in volatility will increase the likelihood of high realizations of food prices.

3 Conceptual Model

In this section we develop a simple model of supply and demand for corn. The ethanol mandate acts to shift the demand for corn outwards. Both supply and demand curves are vulnerable to exogenous shocks in their shifters. We show that these shocks could lead to higher or lower changes in prices for high mandate levels depending on the relative curvatures of the supply and demand functions. The model is depicted graphically in figure 1 and developed analytically below.

Corn demand comes from two sources. Baseline prior demand describes non-RFS corn demand in which corn is largely used for livestock feed, sweeteners, and other food products, as well as as a minor energy source. The ethanol mandate adds a large amount of demand for transportation fuels. Transportation fuel demand is quite price inelastic (Hughes et al. (2008)). The total demand is then the horizontal sum of these two demand sources, or alternatively one can consider the total demand to be shifted out by the ethanol mandate. This is shown in Figure 1 by the shift from D_0 to D_1.

Corn supply has Ricardian increasing marginal costs. It is not directly affected by the mandate, but can be affected an exogenous shifter.

Taken together, the impact of the mandate on price volatility of corn is shown in Figure 1. Under the ethanol mandate, the same amount of exogenous demand shocks (from D_0 to D_0' and from D_1 to D_1') results in a different magnitude of price change. In this representation, ΔP_1 is greater than ΔP_0, because the demand curve under the mandate (D_1) passes the inelastic part of the supply curve. This suggests that the mandate increases price the volatility of corn. However, our analytic model below shows that this result depends on the relative shapes of the supply and demand curves. For instance, Figure 2 shows one possibility in which the mandate decreases corn price volatility. Two critical assumptions in this figure are that the demand side effect of the mandate is an increase in price elasticity of corn demand (i.e. a rotation of the demand curve, rather than rightward shift) and that the supply curve is more inelastic than in Figure 1. Both of the assumptions are necessary. Figure 3 shows that even if the first assumption was satisfied, the mandate induces a larger degree of price volatility when the second assumption is not met (i.e. if demand curves pass elastic portion of the supply curve).

Analytically, we can set a supply curve which is a function of price (P), supply shifter (α), and the mandate (m).

$$\begin{aligned} & S = f(P,\alpha,m) \\ \text{Where} \quad & \frac{\partial f(P,\alpha,m)}{\partial P} = f_p > 0, \\ & \frac{\partial f(P,\alpha,m)}{\partial \alpha} = f_\alpha > 0, \\ \text{and} \quad & \frac{\partial f(P,\alpha,m)}{\partial m} = f_m > 0. \end{aligned} \tag{1}$$

In equation (1), the earlier assumption of increasing marginal cost is reflected in $f_p > 0$ and $f_{pp} < 0$. Also, we assume that $f_\alpha > 0$ and that $f_m > 0$, which are consistent with our argument that the supply side effect of the mandate is the northeast directional movement along the supply curve.

Similarly, we define the demand function as a function of price (P), demand shifter (β), and the mandate (m).

$$\begin{aligned} & D = g(P, \beta, m) \\ \text{Where} \quad & \frac{\partial g(P,\beta,m)}{\partial P} = g_p < 0, \\ & \frac{\partial g(P,\beta,m)}{\partial \beta} = g_\beta > 0, \\ \text{and} \quad & \frac{\partial g(P,\beta,m)}{\partial m} = g_m > 0. \end{aligned} \tag{2}$$

We close the model by assuming markets clear and refer to the market clearing quantity as Q:

$$S = D = Q \tag{3}$$

Now we set up a system of equilibrium equations and find the impact of the mandate on the price volatility by using the Implicit Function Theorem. Rewriting our system yields

$$\begin{cases} Q - f(P, \alpha, m) = 0 \\ Q - g(P, \beta, m) = 0. \end{cases}$$

Then by the Implicit Function Theorem

$$\begin{bmatrix} 1 & -f_p \\ 1 & -g_p \end{bmatrix} \begin{bmatrix} \partial Q/\partial \beta \\ \partial P/\partial \beta \end{bmatrix} = \begin{bmatrix} 0 \\ g_\beta \end{bmatrix}. \tag{4}$$

By applying Cramer's rule, we get

$$\begin{gathered} \frac{\partial P}{\partial \beta} = P_\beta = \frac{g_\beta}{-g_p + f_p} > 0 \\ \because g_\beta > 0, \quad g_p < 0, \quad \text{and} \quad f_p > 0. \end{gathered} \tag{5}$$

Since we are interested in the difference in price changes with and without the mandate, we find $\partial^2 P/\partial\beta\partial m$ by differentiating equation (5).[4] If this is positive, then an increase in the

[4]Formally, the numerator also includes $g_{\beta m}(-g_p + f_p)$. We omit this from equation (6) by assuming that shocks are exogenous to the mandate level, which means that $g_{\beta m} = 0$. One can think of these shocks as being due to weather, exogenous changes in preferences, etc.

mandate will increase the price impacts of demand shocks. If its is less than zero, then an increase in the mandate will reduce the price impact of demand shocks. And if it is zero, the mandate will not affect the price impacts of demand shocks.

$$\frac{\partial^2 P}{\partial \beta \partial m} = P_{\beta m} = \frac{g_\beta \left(g_{pm} - f_{pm}\right)}{\left(-g_p + f_p\right)^2} \tag{6}$$

It is straightforward to see that the sign of $\partial^2 P / \partial \beta \partial m$ will depend on the sign of the numerator. We assume without loss of generality that $g_\beta > 0$, which is essentially a definition of β. Then $\partial^2 P / \partial \beta \partial m$ will have the same sign as $(g_{pm} - f_{pm})$.

Our assumption of increasing marginal costs implies that $f_{pm} < 0$. This is because of the same logic that implies $f_{pp} < 0$. Our supply curve is defined such that the independent variable is price and the dependent variable is quantity. A (inverted) function calculating the supply cost as a function of quantity would have positive first and second derivatives. Because our $f_{pp} < 0$ and the mandate m causes an increase in quantity supplied, $f_{pm} < 0$.

By similar logic, $g_{pm} \leq 0$. Consider a case where the mandate level jumps from 0 to a non-zero quantity. This is equivalent to adding an additional demand source. To get the total demand, one would horizontally sum the original corn demand function (for animal feed, sweeteners, direct human consumption, etc) and the ethanol demand function. If the ethanol demand for corn were perfectly inelastic, this would not change the slope at all and then $g_{pm} = 0$. However, if the ethanol demand for corn is not perfectly elastic, this will flatten out the demand curve. Then $g_{pm} < 0$.

We cannot *a priori* assign a sign to the sum $(g_{pm} - f_{pm})$ because it depends on which value has a larger magnitude. Thus we cannot *a priori* assign a sign to $\partial^2 P/\partial\beta\partial m$. Whether the mandte raises or lowers the price effect of supply shocks is thus an empirical question.

Similarly, we can derive the impact of the demand side shock from equation (4):

$$\frac{\partial P}{\partial \alpha} = P_\alpha = \frac{-f_\alpha}{-g_p + f_p} < 0 \qquad (7)$$
$$\because f_\alpha > 0, \quad g_p < 0, \quad \text{and} \quad f_p > 0.$$

Differentiating and making the simplifying assumption that $f_{\alpha m} = 0$ yields

$$\frac{\partial^2 P}{\partial \alpha \partial m} = P_{\alpha m} = \frac{f_\alpha \left(-g_{pm} + f_{pm}\right)}{\left(-g_p + f_p\right)^2} > 0 \qquad (8)$$
$$\because f_{\alpha m} = 0, \quad f_{pm} < 0, \quad \text{and} \ \ g_{pm} = 0.$$

Again we see that whether a change in β has a larger or smaller impact on prices for when the mandate is increased depends on the relative second derivatives of the supply and demand curves.

While we cannot formally sign these terms, we can consider the likely magnitudes of the effects. The change in the slope of the demand curve g_{pm} is likely to be small, because the additional demand from the mandate is highly inelastic (Hughes et al. (2008)). Additionally, the increase in quantity supplied has been very large and has lead to large-scale land-use clearing to create additional agricultural land (USDA (2015) and Searchinger et al. (2008)). This suggests that the marginal cost of supply has increased dramatically, which would imply a large magnitude of f_{pm}. Taken together, this suggests that $\partial^2 P/\partial\beta\partial m > 0$ and $\partial^2 P/\partial\alpha\partial m > 0$.

4 Econometric models & tests

The model for testing an increase in price volatility for ethanol-related commodities is proposed in equation (9).

$$y_t = \mu + \beta \cdot mandate_t + \mathbf{X_t}\boldsymbol{\gamma} + \theta \cdot trend + \phi_m + \epsilon_t \tag{9}$$

where y_t: outcome variables,

$mandate_t$: mandate volume, linearly interpolated,

$\mathbf{X_t}$: matrix of control variables,

$trend$: time trend, and

ϕ_m: month of year dummies.

We measure price volatility y_t as the absolute value of change in logged prices $|\Delta \log(price_t)|$. This is the magnitude of daily price changes in percentage terms, so a larger value will indicate higher price volatility. We also include a variety of non-agricultural commodity measures to control for broader macroeconomic and financial market phenomena and time trend and month of year fixed effects to control for unobserved time effects. β is the parameter of interest.

Standard unit root tests show that all variables are stationary in absolute values of log differences. This is robust to allowing an endogenously timed structural break. Results are presented in Table 3 and Table 4.

4.1 Identification

The core identification challenge is that we have a single trending treatment in a context where grains are substitutable. We adopt a falsification approach in which we estimate equation 9 for a number of different crops and agricultural commodity products and compare the estimated treatment effect β across each product. If the treatment effect for corn is statistically significantly and economically substantially larger than the an effect for other products, that suggests that the effect is due to the ethanol mandate. If these products are substitutes, then an increase in demand for corn could lead to an increase in demand for other products. Thus any differential effect should be considered a lower bound on the actual treatment effect.

For falsification, we estimate equation (9) for coffee, cotton, lumber, oats, rice, soybean, soybean meal, sugar and wheat.

5 Data

We use daily trading data (five days a week) with the only exception being mandate volume which is annual. Within the time span from 01-01-1987 to 12-13-2013, there existed some missing values, and prior date prices are used for those gaps. The ethanol mandate volume is linearly smoothed.

Among independent variables, crop prices for corn, soybean and wheat are Chicago Board of Trade (CBOT) futures settle prices (front month) and in US dollars per bushel. We also use three economic variables to control market conditions: (1) Dow-Jones industrial average indices (DJ), a proxy for economic conditions; (2) West Texas Intermediate (WTI) spot prices (USD per barrel), which enables us to take into account that energy prices are related to the input cost of crop production[5]; and (3) a weighted average of the foreign exchange value of the US dollar against a subset of the broad index currencies (ER).[6] All price-related variables such as grain prices and WTI are depreciated using the monthly US Consumer Price Index (CPI, 2010=1.00).

Table 1 shows descriptive statics of variables, and Figure 4 presents corn prices and mandate

[5]Prices of crude oil and its products have bearing on prices of fertilizer, diesel-fuled farming equipments, transportation costs, etc.

[6]Major currencies index includes the Euro area, Canada, Japan, United Kingdom, Switzerland, Australia, and Sweden.

volume over time. It seems that a decreasing trend in corn prices prevails through the 90s and then it turns around in the early 2000s. Similarly, ethanol mandate volume has been increasing since 2006. Table 2 presents both price levels and y_t before and after the mandate. It is apparent that corn price volatility increased after the mandate, but of course that is an unconditional comparison. Full regression results are presented below.

6 Results

The result of estimating equation (9) is presented in Table 5. The most noteworthy result in this table is that the coefficient of the mandate in the model for corn is positive and statistically different from zero at a 1 percent significance level. This result supports our earlier assertion that the mandate inflates the magnitude of an exogenous shock. Coefficients for economic control variables (Dow-Jones Index, WTI, and exchange rate) generally are significant and have expected signs. Coffee and lumber are the exception. The imported share of the total U.S. coffee consumption is considerably high; therefore, the price volatility of coffee is likely influenced by other factors than the economic condition of the United States. When it comes to lumber, its unique growth process makes it distinct from all other grains in this study. That is, unlike other crops, lumber is not harvested in a year after sowing. Rather, it may take decades to harvest wood, so price linkage may be complex.

Identification relies upon a series of falsification tests. As we observe in Table 5, soybean meal and sugar also have positive and statistically significant point estimates for the effect of the mandate. These commodities are particularly closely linked to corn and are thus particularly vulnerable to volatility spillovers. Table 6 shows the results of a series of t-tests comparing the estimate of the effect of the mandate β on each commodity to the effect of the mandate on corn. We can reject the null that each commodity's β equals corn's β for all commodities except sugar. In other words, although the mandate seems to have significant impacts on other crop price volatilities, the mandate's effect on corn volatility is statistically larger than on other agricultural goods. This effectively bolsters the prediction that the mandate increased price volatility of ethanol-related commodities.

We cannot reject the null that sugar price volatility increased by as much as corn price volatility. Sugar and corn are substitutes as sweeteners and previous researchers have found that their prices are closely related.[7] Thus the increase in demand for corn may have also increased demand for sugar and thus sugar price volatility.

Haley (2011) and Landes (2010) provide evidence that sugar price volatility increased during the period of the ethanol mandate for unrelated regions. Haley argue that cane and beet sugar costs and fructose syrup costs increased in 2008-2009 due to an upsurge in fuel and chemical costs. Landes (2010) provides more evidence. Landes argues that capricious Brazil's exchange rate, sugar-ethanol tradeoff, and decreased production in Asia (mostly driven by sugar policies of India, the world's largest sugar consuming country) contributed to the sugar price spike in 2009–2010. They also point out that although the US sugar market has been insulated from the world market by the government's policy, full implementation of the North American Free Trade Agreement (NAFTA) in 2008 exposed the US domestic sugar market to shocks in foreign markets. These arguments suggest that there were other factors that drove high sugar price volatility in 2008–2010 which happens to be consistent with the emergence of the ethanol man-

[7] ICE argue that the sugar trade linked sugar prices to prices of corn-derived ethanol, and hence to the price of corn itself. They suggest that rolling six-month correlations of returns between sugar and both corn and gasoline reached unprecedented levels which reinforces the argument. Rapsomanikis and Hallam (2006) also report that sugar and ethanol prices are linearly cointegrated. In the context of the sweetener market, Moss and Schmits (2002) contend that there exists a substitution between high fructose corn syrup (HFCS) and sugar although the cointegration is not observed after 1996.

date era. If this is the case, significant impact of the ethanol mandate on sugar price volatility is spurious.

We also find evidence of a structural break in corn prices concurrent with the start of the policy, which supports our core finding that the ethanol mandate changed corn price dynamics. Table 4 presents the results of a Zivot-Andrews test. Note that we see evidence of a breakpoint for corn prices at the start of the mandate. We also see evidence of a concurrent breakpoint in wheat prices, which is unsurprising as wheat is a close substitute for corn.[8] Furthermore, note that no other commodities show evidence of a break near the start of the mandate. While again only suggestive, this supports our hypothesis that the ethanol mandate changed the dynamics of corn prices.

7 Conclusion

The Renewable Fuels Standard and RFS 2 were designed to promote energy security and reduce greenhouse gases from gasoline consumption. However, benefits should be balanced against costs - both potential environmental costs and spillovers into other markets. A number of recent studies have shown that the corn ethanol mandate has increased corn prices. High food prices can have substantial welfare implications, particularly in low-income countries.

This paper develops a theoretical model of price volatility and shows that the ethanol mandate could in principle either increase or decrease price volatility. Using direct estimation and a series of falsification tests, we provide suggestive evidence that the mandate has indeed in-

[8]The close relationship between corn and wheat prices is not novel, having been previously documented. For instance, Mitchell (2008) argues that wheat competes with corn in land use.

creased price volatility, which could lead to a higher likelihood of high realizations of prices. This could have substantial welfare implications, particularly in low-income countries. Further research continuing to explore the determinants of price volatility would hold substantial value.

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Figures

Figure 1: Conceptual Model

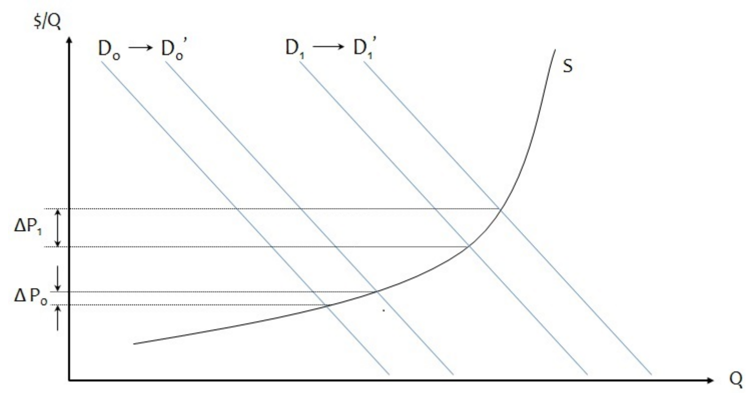


Figure 2: Conceptual Model—Decrease in Volatility

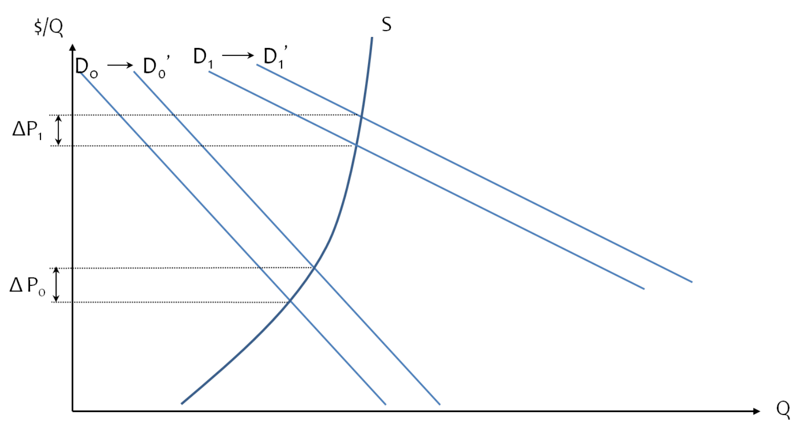


Figure 3: Conceptual Model—Increase in Volatility

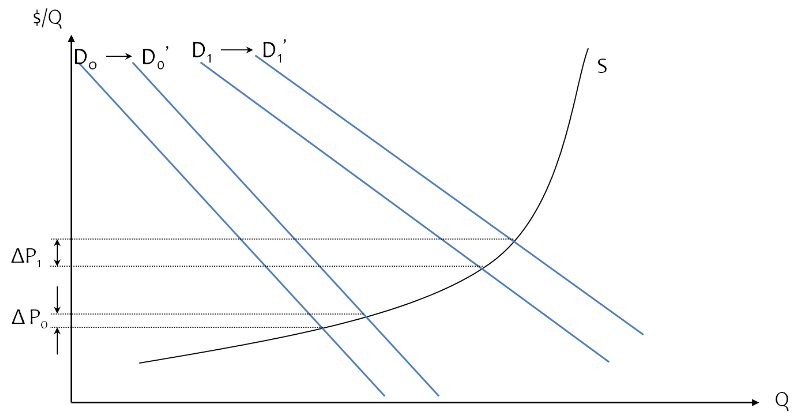
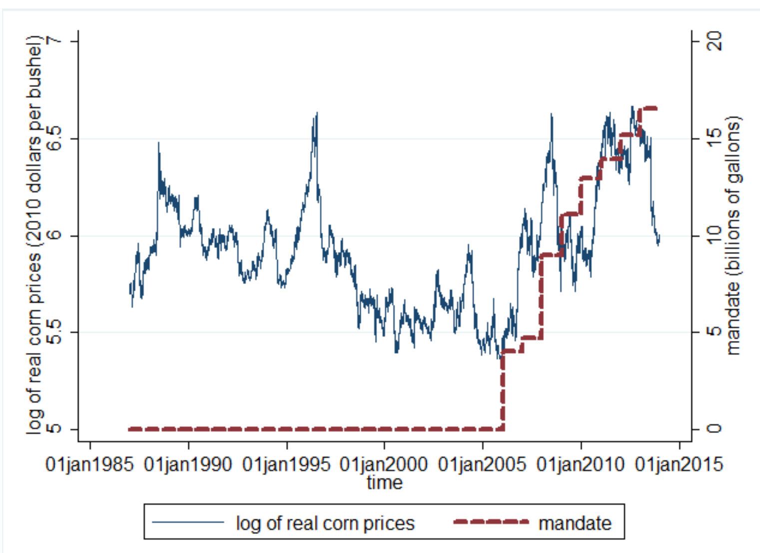


Figure 4: Trends of corn prices and mandate



Tables

Table 1: Descriptive statistics

VARIABLES	Unit	(1) N	(2) mean	(3) sd	(4) min	(5) max
Levels						
Dow-Jones index	N/A	6,800	7,963	3,934	1,739	16,577
Exchange rate	N/A	6,800	87.87	10.11	68.00	113.1
Mandate volume	Billions of gallons	6,800	3.240	5.522	0	17.24
Coffee	Cents per pound	6,800	148.4	59.39	51.01	377.8
Corn	Cents per bushel	6,800	389.3	126.1	205.0	788.2
Cotton	Cents per pound	6,800	88.50	29.47	35.02	210.4
Lumber	Dollars per 1000 board feet	6,800	351.1	97.04	142.1	749.3
Oats	Cents per bushel	6,800	243.0	79.06	118.4	698.5
Rice	Cents per cwt	6,800	11.63	3.560	4.167	24.93
Soybean meal	Dollars and Cents per bushel	6,800	287.4	77.37	159.5	600.6
Soybean	Cents per bushel	6,800	950.3	261.5	512.9	1,958
Sugar	Cents per pound	6,800	14.96	5.361	5.911	34.71
Wheat	Cents per bushel	6,800	531.2	154.8	289.4	1,312
WTI crude oil	Dollars per barrel	6,777	48.29	25.89	14.35	144.7
Absolute value of first difference in logs						
Dow-Jones index		6799	0.008	0.009	0	0.256
Exchange rate		6799	0.003	0.003	0	0.041
Coffee		6799	0.016	0.017	0	0.238
Corn		6799	0.012	0.013	0	0.276
Cotton		6799	0.013	0.013	0	0.304
Lumber		6799	0.015	0.015	0	0.204
Oats		6799	0.015	0.017	0	0.255
Rice		6799	0.012	0.013	0	0.281
Soybean meal		6799	0.012	0.013	0	0.205
Soybean		6799	0.011	0.012	0	0.234
Sugar		6799	0.016	0.016	0	0.236
Wheat		6799	0.014	0.013	0	0.286

Table 2: Descriptive statistics - Comparison between pre- and post-mandate grain price volatilities

	pre-mandate						post-mandate					
	Levels			Absolute value of first difference in logs			Levels			Absolute value of first difference in logs		
VARIABLES	N	mean	sd	N	mean	sd	N	mean	sd	N	mean	sd
Corn	4,791	349.5	89.82	4,790	0.010	0.011	2,009	484.4	147.5	2,009	0.016	0.015
Coffee	4,791	148.1	64.71	4,790	0.017	0.018	2,009	149.2	44.22	2,009	0.014	0.014
Cotton	4,791	93.13	28.03	4,790	0.012	0.013	2,009	77.45	29.89	2,009	0.015	0.014
Lumber	4,791	389.1	85.29	4,790	0.015	0.015	2,009	260.5	53.71	2,009	0.016	0.017
Oats	4,791	221.1	74.39	4,790	0.015	0.017	2,009	295.1	64.11	2,009	0.016	0.016
Rice	4,791	10.83	3.606	4,790	0.012	0.013	2,009	13.53	2.594	2,009	0.012	0.011
Soybean meal	4,791	273.8	72.77	4,790	0.011	0.012	2,009	319.9	78.37	2,009	0.014	0.015
Soybean	4,791	883.4	228.1	4,790	0.010	0.011	2,009	1,110	267.1	2,009	0.013	0.014
Sugar	4,791	13.79	4.695	4,790	0.016	0.016	2,009	17.75	5.805	2,009	0.017	0.016
Wheat	4,791	488.0	132.5	4,790	0.012	0.012	2,009	634.0	155.9	2,009	0.017	0.015

Table 3: Testing for unit roots

	Corn	Coffee	Cotton	Lumber	Oats	Rice	Soybean
$Z(\tau)$	-66.673***	-70.732***	-68.891***	-70.711***	-71.584***	-60.308***	-69.176***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Soybean meal	Sugar	Wheat	Dow-Jones	WTI	Exchange Rate	
$Z(\tau)$	-70.824***	-64.907***	-63.856***	-68.619***	-66.285***	-67.807***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

p-values in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Notes: Variables used in Phillips-Perron Tests are in absolute values of first difference in logs

Table 4: Testing for unit roots: Allowing for a structural break for an unknown point

	Corn	Coffee	Cotton	Lumber	Oats	Rice	Soybean	Soybean meal	Sugar	Wheat
Minimum t-statistic	-16.838***	-20.069***	-19.231***	-20.552***	-19.151***	-17.788***	-16.837***	-18.008***	-19.106***	-19.685***
Breakpoint	04-28-2006	06-10-1992	05-02-2000	12-29-1992	06-27-2001	02-24-1999	08-08-2003	08-23-1991	08-21-1998	05-05-2006

p-values in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Notes: Variables used in Zivot-Andrews tests are in absolute values of first difference in logs

Table 5: Results of estimation: testing for increase in volatility

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Corn	Coffee	Cotton	Lumber	Oats	Rice	Soybean	Soybean meal	Sugar	Wheat
mandate	0.0003***	-0.0004***	-0.0000	-0.0003***	0.0001	-0.0002***	-0.0000	0.0001*	0.0003***	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dow-Jones	0.0784***	-0.0178	0.0747***	0.0409*	0.0829***	0.0848***	0.0682***	0.0544***	0.0803***	0.1051***
	(0.019)	(0.021)	(0.019)	(0.022)	(0.026)	(0.017)	(0.023)	(0.019)	(0.028)	(0.020)
Exchange rate	0.2241***	0.1165*	0.3074***	0.0839	0.2438***	0.2067***	0.3259***	0.2196***	0.2600***	0.2287***
	(0.060)	(0.071)	(0.058)	(0.068)	(0.077)	(0.058)	(0.066)	(0.055)	(0.070)	(0.065)
WTI	0.0536***	0.0158	0.0248***	0.0028	0.0549***	0.0304***	0.0461***	0.0287***	0.0269**	0.0571***
	(0.010)	(0.012)	(0.009)	(0.010)	(0.013)	(0.012)	(0.010)	(0.009)	(0.012)	(0.012)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Notes: Results for month of year dummies are omitted.

Table 6: Hypothesis testing on coefficients of mandates

	Coefficient of mandate	p-value (for the t-test)
Corn	0.0003	-
Coffee	-0.0004	0.000***
Cotton	-2.95e-06	0.000***
Lumber	-0.0002	0.000***
Rice	-0.0002	0.000***
Soybean	-0.0000	0.000***
Soybean meal	0.0001	0.001***
Oats	0.0001	0.021**
Wheat	0.0001	0.000***
Sugar	0.0003	0.734

* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Notes: