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The Effect of Ethanol Production on the U.S. National Corn Price

by

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The Effect of Ethanol Production on the U.S. National Corn Price

Abstract

A system of equations representing corn supply, feed demand, export demand, food, alcohol and industrial (FAI) demand, and corn price is estimated by three-stage least squares. A price dependent reduced form equation is then formed to investigate the effect of ethanol production on the national average corn price. The elasticity of corn price with respect to ethanol production is then obtained. Results suggest that ethanol production has a positive impact on the national corn price and that the demand from FAI has a greater impact on the corn price than other demand categories. Thus, significant growth in ethanol production is important in explaining corn price determination.

Keywords : corn price, ethanol, simultaneous equations, three-state least squares, elasticity

Introduction

Ethanol production in the U.S. has grown tremendously in the last decade. Production was averaging 1 billion gallons per year in the early 1990s, grew to 4 billion gallons in 2005, and in 2006 exceeded 5 billion gallons (Renewable Fuels Association (RFA), Figure 1). If current plans for new construction and expansion come to fruition, production capacity will exceed 11 billion gallons by the end of 2007. Recent growth has been supported by the combination of favorable public policy and high nominal gasoline prices.

Most U.S. ethanol is made from corn. The U.S. industry used a record 13% of domestic corn production in 2005 (RFA) and is expected to use over 20% in the 2006/2007 marketing year (USDA).[1] As the ethanol industry has increased its share of corn use, concern has developed relative to ethanol's impact on corn price, and as a result other corn users.

The purpose of this research is to examine the effect of ethanol production on the U.S. national corn price. While the popular press often refers to the impact, a comprehensive analysis of ethanol's impact has been lacking. This research investigates the effect of ethanol production on corn price through estimation of a system of simultaneous equations that represent the supply/demand relationships in the corn market. The paper proceeds with a review of relevant literature, followed by a description of the model, data and methods. Results and conclusions are presented at the end.

Literature review

There have been several studies focused on relating increased ethanol production to changes in corn markets. Gustafson (2002) found that farmers in the northwest region of North Dakota were readily able to expand corn acreage for ethanol production, provided adequate market incentives were available. He estimated that 154,000 additional North Dakota acres of corn could be obtained with market premium of $0.11 per bushel.

Ferris and Joshi (2004) considered several scenarios in analyzing the impact of increased ethanol demand on crop and feed prices, and on farm income and state finances given the current tax-

[1] The marketing year for U.S. corn runs from September to August.

subsidy structure. This was done utilizing a multi-sector econometric model (AGMOD). Based on their high demand scenario of 4.67 billion gallons of ethanol production by 2010, they estimated an increase of eighteen percent in farm level corn prices for 2007. They further concluded that agricultural commodity prices would increase sharply in the short run followed by more moderate increases due to expanded corn acreage.

McNew and Griffith (2005) examined local grain price impacts associated with ethanol plants. They based their work on a sample of twelve ethanol plants that opened between 2001 and 2002. They found that the ethanol plants increased local grain prices (i.e., the basis), but the impact was not uniform across plants nor around a specific plant. On average, corn prices increased by 12.5 cents per bushel at the plant site, and some positive price response was felt up to 150 miles away. However, price responses at the plant ranged from less than 5 cents per bushel to just under 20 cents per bushel. Similarly, the range of price impacts up to 150 miles away was also quite large.

Taylor, Mattson, Andino and Koo (2006) developed a simulation model to estimate the impact of changes in ethanol production on corn production, consumption, exports and price. They found that changes in ethanol production impact corn production, feed use, and exports, as well as corn price under a variety of scenarios. They estimated that the corn price for 2014 will average $2.46 per bushel if ethanol production reaches the 7 billion gallon mark as outlined in the 2005 Energy Bill. If 14 billion gallons of ethanol are produced, they estimated the price of corn would average $3.00 per bushel in 2014.

Since ethanol production is not near 14 billion gallons yet and average corn prices in spring 2007 far exceeded Taylor et al.'s estimate for 2014, the national average impact deserves further consideration.

Structural Model and Specification

This work differs from previous research in that it focuses on estimating the short-run corn price elasticity associated with ethanol production. It does this by way of a system of supply/demand equations that reflect the national corn market. All equations in the system are specified as log-log models (some call this specification a log-linear model). The parameters of the log-log model can be directly interpreted as elasticities (Gujarati). The log-log model assumes a constant elasticity over all values of the data set. The initial model specification is of the form :

$$y_t = \alpha z_t^{\beta} x_t^{\gamma} e^{\delta D_t} e^{\varepsilon_t} \quad (1)$$

where α,β,γ and δ are parameters to be estimated, and z_t and x_t are endogenous and exogenous variables, respectively. D_t is a time reflecting dummy variable and *e* is the exponential function. Taking logs of variables in equation (1) yields

$$Y_t = \alpha' + \beta z_t' + \gamma x_t' + \delta D_t + \varepsilon_t \quad (2)$$

with the traditional assumptions for the error term, namely $\varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right)$.

All data are transformed by logs except the dummies and a trend variable. As usual, it is assumed that the disturbance term is uncorrelated with the exogenous variables used as instruments, but is correlated with the endogenous variables. That is, $E\left(z_t\varepsilon_t\right) \neq 0$ and $E\left(x_t\varepsilon_t\right) = 0$.

Prices of many agricultural products are related, and this often results in specifying multi-market partial equilibrium models, e.g., models of both the feed grain and livestock sectors that account for interaction across markets (Tomek and Myers, 1993). As an example, Arzac and Wilkinson (1979) present a quarterly econometric model of the U.S. livestock and feed grain markets with 42 equations. For the purposes here, however, model specification is limited to the U.S. corn market even though interaction with other markets is to be expected. The extension of the current research to a multi-market structure is the topic of future research.

Based on United States Department of Agriculture (USDA) categories, corn is utilized for feed, exports and food, alcohol and industrial use (FAI).[2] Chambers and Just (1981) aggregated food disappearance and feed disappearance for domestic corn use to investigate the effect of exchange rate fluctuations on the corn market, while others usually disaggregate the demand into several components.[3] Since the focus of this work is on the effect of each category of corn demand on U.S. corn price, corn demand is separated into feed, export and FAI. Demand from feed and exports have been relatively flat over time (though they show seasonality), but FAI consumption has been increasing rapidly (Figure 2). Currently, about half of FAI demand goes to the production of ethanol (Figure 3).

It is assumed the price of corn is determined by supply and the three sectors of demand simultaneously. In this system, there are separate equations for corn supply, corn price, feed demand, export demand and FAI demand. Each equation is explained below. The approach adopted here is different from many previous applications of supply/demand models. For instance, Chambers and Just (1981) and Devadoss et al. (1989) first model corn supply and use functions and then derive a price dependent reduced form equation from equilibrium conditions (supply is equal to disappearances and stocks). That is, the price equation is expressed as a function of all exogenous variables. However, this makes it difficult to estimate effects of other endogenous variables on the corn price.

Corn supply in this research is predetermined in the sense that it is the value of ending stocks from the previous period. The decision of how much corn to carry forward is dependent on physical storage costs and the opportunity cost of capital tied up in inventory. If the storage costs (including the opportunity costs) are high enough, minimal stocks will be carried forward. On the other hand, if the carrying costs are relatively low compared to expected price appreciation, ending stocks will tend to be large. The carrying costs can be approximated by the differences in current and later prices (returns to physical storage) and discounted by current interest rates (as a proxy for foregone income resulting from holding inventory). Thus, corn supply in the current period is determined by the previous period's corn price and interest rate. However, because of serial correlation in the corn price, it seems reasonable to include corn supply in the list of endogenous variables even though it is predetermined. Tomek and Myers (1993) discussed this

[2] The Economic Research Service, USDA issues corn utilization values for feed and residual, export, and FAI quarterly. They have a separate value for seed use but we ignore the seed use since it is small.
[3] In Devadoss et al. (1989), demand for corn is disaggregated into food use, feed use, seed use, stocks, and exports.

issue for apples and argued that current production and beginning inventories are predetermined, but prices and allocations of quantities to alternate end-uses may be simultaneously determined.

Following the Tomek and Myers' argument, 5 endogenous variables are identified in the corn system. These include price, supply, feed, export and FAI. For purposes of comparison, an alternative system of equations that treats corn supply as exogenous is also estimated.

The initial system of 5 equations is estimated by three-stage least squares (3SLS). The alternative system (treating supply as exogenous) first estimates the supply equation via OLS, and then the other four equations via 3SLS. Prior to estimation, each equation is tested for autocorrelation by application of the Breusch-Godfrey Lagrange Multiplier test. This is done by estimating each equation via OLS individually. Results confirm that the supply, export and price equations exhibit first order autocorrelation. This is corrected by adding a one period lagged dependent variable to the right hand side of the three equations.

<u>Supply equation</u>

The supply of corn for each quarter is composed of beginning stocks (same as ending stocks from the previous quarter) and production (we ignore imports).[4] Harvest occurs only in the 1st quarter of the year. Thus, the supply of corn for the 1st quarter is the sum of the beginning stocks and production. For the rest of the quarters, the supply is only the beginning stocks. The supply of corn is a function of one period lagged corn price and one period lagged interest rate. Since the supply for this period is equal to the ending stocks of last period, it is determined by the previous period's price and interest rate. If the corn price was high in the previous period relative to futures prices, farmers will tend to reduce carryover because of the large cost of carry. Also, if the interest rate was high in the previous period, farmers will reduce carry over since the opportunity cost of holding inventory is high.[5] The supply equation takes the form :

$$S_t = \alpha_0 + \alpha_1 P_{t-1}^C + \alpha_2 R_{t-1} + \alpha_3 S_{t-1} + \alpha_4 D_1 + \alpha_5 D_2 + \alpha_6 D_3 + \varepsilon_{1t} \quad (3)$$

where S_t is supply of corn for quarter t, P_{t-1}^C is the lagged corn price and R_{t-1} is the lagged interest rate. D_1, D_2 and D_3 are quarterly dummies for the 1st quarter, the 2nd quarter and the 3rd quarter, respectively. The signs of α_1 and α_2 are expected to be negative and α_3 positive. The supply equation has one endogenous variable (S_t) and six exogenous variables ($P_{t-1}^C, R_{t-1}, S_{t-1}, D_1, D_2$ and D_3).

[4] Corn production is defined as a function of acreage planted, yield and government program in several previous papers (Arzac and Wilkinson, 1979, Tomek and Myers, 1993, and Garcia and Leuthold, 1997). Price expectation, risk and technology also play a role in determination of production. In the present research, production is treated as exogenous. However, corn supply (including production) is treated as endogenous and the 1st quarter dummy variable captures the production effect in the supply equation.

[5] A similar argument is provided in Chambers and Just (1981), but the inventory equation in their paper is determined by lagged inventory, own price, production and quarterly indicator variables.

Feed equation

Corn feed consumption is a function of corn price, soybean meal price (a substitute for corn) and number of animals on feed (specifically cattle, hogs and broilers). It takes the form :

$$F_t = \beta_0 + \beta_1 P_t^C + \beta_2 P_t^{SM} + \beta_3 B_t + \beta_4 COF_t + \beta_5 H_t + \beta_6 D_1 + \beta_7 D_2 + \beta_8 D_3 + \varepsilon_{2t} \quad (4)$$

where F_t is feed consumption, P_t^C is corn price, P_t^{SM} is soybean meal price, B_t is the number of broilers, COF_t is the number of cattle on feed and H_t is the number of hogs. The expected sign of β_1 is negative and the expected signs of $\beta_2, \beta_3, \beta_4$ and β_5 are all positive. There are two endogenous variables (F_t , P_t^C) and seven exogenous variables (P_t^{SM} , B_t, COF_t , H_t , D_1 , D_2 and D_3) in the feed equation.

Export equation

Corn exports are modeled as a function of corn price, wheat production in other countries, per capita GDP of major U.S. corn importers, and exchange rates. More than 60% of U.S. corn exports go to five countries; Japan, Mexico, Taiwan, Egypt and Korea.[6] The per capita GDP for the importers is calculated as the weighted average of the 5 countries' per capita GDP. The weight is determined by the proportion of corn exported to each country from 1997 to 2005.

The impact of exchange rates is measured by the dollar index. The dollar index is a weighted average of the exchange rates between the U.S. Dollar and six major world currencies.[7] In Chambers and Just (1981), corn exports are represented as a linear function of own-deflated price, the exchange rate, stocks of corn in the other major exporting nations, the price of soybeans, the lagged dependent variable, and the quarterly indicator variables. The exchange rate they used was the Special Drawing Rights (SDR) per dollar.[8] Today, use of SDR is limited and its main function is to serve as the unit of account of the International Monetary Fund (IMF) and some other international organizations (IMF). As a result, use of the dollar index as a proxy for the U.S. Dollar exchange rate is now more acceptable. The export equation takes the form :

$$EX_t = \gamma_0 + \gamma_1 P_t^C + \gamma_2 EX_{t-1} + \gamma_3 W_t^{row} + \gamma_4 DX_t + \gamma_5 GDP_t + \gamma_6 D_1 + \gamma_7 D_2 + \gamma_8 D_3 + \varepsilon_{3t} \quad (5)$$

where EX_t is exports, W_t^{row} is wheat production in the rest of world, DX_t is the dollar index, and GDP_t is the per capita GDP of the main corn importing countries. Corn exports will decrease as the U.S. Dollar strengthens (higher dollar index) and world wheat production increases, and will increase with increases in import countries' GDPs. Therefore, γ_5 is expected to be positive

[6] This was calculated by the authors based on data from USDA.
[7] The dollar index consists of the Euro, the Japanese Yen, the British Pound, the Canadian Dollar, the Swedish Krona ,and the Swiss Franc (from New York Board of Trade).
[8] This is defined as a basket of currencies consisting of the U.S. Dollar, the Deutsche Mark, the Japanese Yen, the British Pound, and the French Franc, and is calculated by the IMF.

and γ_1, γ_3 and γ_4 all negative. The export equation has two endogenous variables (EX_t, P_t^C) and seven exogenous variables ($W_t^{row}, EX_{t-1}, DX_t, GDP_t, D_1, D_2$ and D_3).

FAI equation

Corn FAI consumption is a function of corn price, ethanol production and U.S. population. A linear trend variable is added to capture the increase in ethanol production over time. The model is specified as :

$$FAI_t = \delta_0 + \delta_1 P_t^C + \delta_2 Eth_t + \delta_3 Pop_t + \delta_4 T_t + \delta_5 D_1 + \delta_6 D_2 + \delta_7 D_3 + \varepsilon_{4t} \quad (6)$$

where FAI_t is FAI consumption, Eth_t is ethanol production in the U.S., Pop_t is U.S. population and T_t is a linear trend. The expected sign of δ_1 is negative and δ_2 positive. The FAI equation has two endogenous variables (FAI_t, P_t^C) and six exogenous variables (Eth_t, Pop_t, T_t, D_1, D_2 and D_3).

Price equation

The price of corn is determined by supply and demand simultaneously. Also, the price affects the supply and demand of corn. The corn price model is :

$$P_t^C = \zeta_0 + \zeta_1 S_t + \zeta_2 F_t + \zeta_3 EX_t + \zeta_4 FAI_t + \zeta_5 P_{t-1}^C + \zeta_6 D_1 + \zeta_7 D_2 + \zeta_8 D_3 + \varepsilon_{5t} \quad (7)$$

The sign of ζ_1 is expected to be negative and the signs of ζ_2, ζ_3 and ζ_4 to be positive. The price equation has five endogenous variables (P_t^C, S_t, F_t, EX_t and FAI_t) and four exogenous variables (P_{t-1}^C, D_1, D_2 and D_3).

Data and Methodology

Data

The data for the empirical analysis is comprised of quarterly data for 11 years. It spans 2nd quarter 1995 (Dec, 1995) to 1st quarter 2006 (Nov, 2006). The data are structured to coincide with the marketing year for U.S. corn. That is, the 1st quarter is from Sep to Nov, the 2nd quarter from Dec to Feb, the 3rd quarter from Mar to May and the 4th quarter runs from Jun to Aug. Quarterly data are used to coincide with the quarterly release of USDA data on stocks. Similar to Lowry et al (1987), it is assumed that the preceding year's crop is harvested in quarter 1 and the current year's crop is planted in quarter 3.

Most price, stock, production, corn usage and livestock data are obtained from various USDA reports. The corn price is measured as the quarterly average of the USDA reported monthly average farm level price. The soybean meal (49-50 percent) price is the quarterly average of monthly wholesale prices in Illinois. The corn stocks are measured via the USDA quarterly stocks reports, and represent the size of the beginning stocks as of Mar 1, Jun 1, Sep 1 and Dec 1.

Feed, exports and FAI consumption are also measured quarterly. The number of cattle on feed is the quarterly average of monthly data, and the number of broilers is the quarterly average of weekly data. Hog numbers are measured as the average of the beginning inventory and ending inventory in each quarter.

The dollar index is obtained from the web site of the Board of Governors of the Federal Reserve System. It is a nominal broad dollar index and is a quarterly average of monthly data. The GDP per capita for importing countries and the U.S. population are from IMF, and are constant during a year. GDP per capita is the annual number in current price. Ethanol production is calculated from Energy Information Administration, and is the quarterly sums of monthly production.

Methodology

The impact of ethanol production on national average corn price is measured by a system of equations that explain the supply/demand fundamentals of the U.S. corn market. The system is comprised of a single supply equation, a set of three demand equations, each focused on a specific category of demand (as defined by the World Agricultural Supply and Demand Estimates, and ERS), and a price equation.

Before estimating the system of equations, identification is verified by calculating order and rank conditions. All five equations are found to satisfy the requirement for the order and rank condition.[9] The order condition is a necessary condition and the rank condition is a necessary and sufficient condition for identification. Since the model meets these conditions, it can be solved for a unique solution.

There are several methods for estimating simultaneous equations. The two-stage least squares estimator (2SLS), one of the most popular, is efficient and consistent but it ignores information concerning the endogenous variables that appear in the system but not in individual equations (Judge et al.). Information concerning the error covariances is also lost (Judge et al.). Another popular method, seemingly unrelated regression (SUR), accounts for the correlation in the error terms across equations but does not consider the endogenous problem in each equation. Three-stage least squares is considered a combination of 2SLS and SUR. It accounts for the contemporaneous correlation in the error terms across equations and the correlation of the right hand side variables with the error term. Furthermore, it is asymptotically more efficient than 2SLS (Judge et al.).

Based on these characteristics, 3SLS is used to estimate the system of simultaneous equations for the corn market. For equations (3) to (7), as mentioned earlier, it is assumed that the endogenous variables are correlated with the error term in each equation and the error terms across the equations are also correlated. Initially, the five equations are estimated by 3SLS. Then as an alternative, the supply function is estimated by OLS and the remaining four equations are

[9] The verification is available upon request.

estimated by 3SLS. The two sets of results are compared to determine whether there are advantages of one model structure over another.

Results

Regression results are presented in tables 1 and 2. The tables specify the first model (5 endogenous variables) as the "base" and the second model (4 endogenous variables) as the "alternative". In both cases, all estimated coefficients have the expected signs. The coefficients directly imply elasticity since the values are transformed to logarithms. All but the export equations have very high R square values. Over 90 percent of the variation in the supply, feed and FAI variables are explained by the model. The price variable is also well explained. However, the export equation has a lower R square than the others. This is likely due to the influence of international factors not included in the model. The Root Mean Squared Errors of each equation for both the base and alternative specifications are very similar and are stable. Consequently, it does not appear that one model is superior to the other. As such, the following discussion is based on the base model.

In the three demand equations (feed, export and FAI), the corn price coefficient is negative as expected. However, the price equation reveals an interesting result. The effect of each demand factor on the corn price varies significantly. The impact of FAI consumption on corn price is the greatest in terms of the magnitude of coefficients. Export consumption has the second greatest impact, and feed consumption follows.[10] However, the impact of feed consumption on the corn price is not statistically significant even though feed consumption is the largest single use of corn. Results suggest that increasing demand from FAI is more important in explaining corn price than other use categories. Thus, growth in ethanol production is important in explaining corn price determination.

The effect of increasing production of ethanol on the corn price, that is the elasticity of corn price with respect to ethanol production, $\frac{\partial P_t^c}{\partial Eth_t}$, can be calculated from the price dependent reduced form equation. After substituting equations (3), (4), (5) and (6) into the price equation (7), we have the following reduced form equation.

$$P_t^C = \frac{B}{A} + \frac{1}{A}\begin{bmatrix} \left(\alpha_1\zeta_1 + \zeta_5\right) P_{t-1}^C + \alpha_2\zeta_1 R_{t-1} + \alpha_3\zeta_1 S_{t-1} + \beta_2\zeta_2 P_t^{sm} + \beta_3\zeta_2 B_t + \beta_4\zeta_2 COF_t + \beta_5\zeta_2 H_t \\ +\gamma_2\zeta_3 EX_{t-1} + \gamma_3\zeta_3 W_t^{row} + \gamma_4\zeta_3 DX_t + \gamma_5\zeta_3 GDP_t + \delta_2\zeta_4 Eth_t + \delta_3\zeta_4 Pop_t + \delta_4\zeta_4 T_t \\ +CD_1 + DD_2 + ED_3 \end{bmatrix} + v_t$$

where

[10] Chambers and Just (1981) report the own price elasticity of domestic disappearances and export as -.125 and -.465, respectively. The present research finds a less inelastic result for domestic disappearances and a more inelastic result for exports.

$$A = 1 - \beta_1\zeta_2 - \gamma_1\zeta_3 - \delta_1\zeta_4$$
$$B = \zeta_0 + \alpha_0\zeta_1 + \beta_0\zeta_2 + \gamma_0\zeta_3 + \delta_0\zeta_4$$
$$C = \alpha_4\zeta_1 + \beta_6\zeta_2 + \gamma_6\zeta_3 + \delta_5\zeta_4 + \zeta_6$$
$$D = \alpha_5\zeta_1 + \beta_7\zeta_2 + \gamma_7\zeta_3 + \delta_6\zeta_4 + \zeta_7$$
$$E = \alpha_6\zeta_1 + \beta_8\zeta_2 + \gamma_8\zeta_3 + \delta_7\zeta_4 + \zeta_8$$
$$v_t = \frac{1}{A}\left[\zeta_1\varepsilon_{1t} + \zeta_2\varepsilon_{2t} + \zeta_3\varepsilon_{3t} + \zeta_4\varepsilon_{4t} + \varepsilon_{5t}\right]$$

Then

$$\frac{\partial P_t^C}{\partial Eth_t} = \frac{\delta_2\zeta_4}{A} = \frac{\delta_2\zeta_4}{1 - \beta_1\zeta_2 - \gamma_1\zeta_3 - \delta_1\zeta_4}$$

The results suggest that ζ_2 (the feed consumption coefficient in the price equation) is not statistically significant at the 5% level. However, the variable is kept in the reduced form equation to capture the joint interaction of corn price and feed demand. The ethanol production elasticity of corn price and asymptotic variance are equal to

$$\frac{\partial P_t^C}{\partial Eth_t} = \frac{0.40 * 0.45}{1 - (-.30) * .09 - (-.26) * .27 - (-0.08) * 0.45} = 0.16$$
$$Asy.Var\left(\frac{\partial P_t^C}{\partial Eth_t}\right) = 0.00135$$

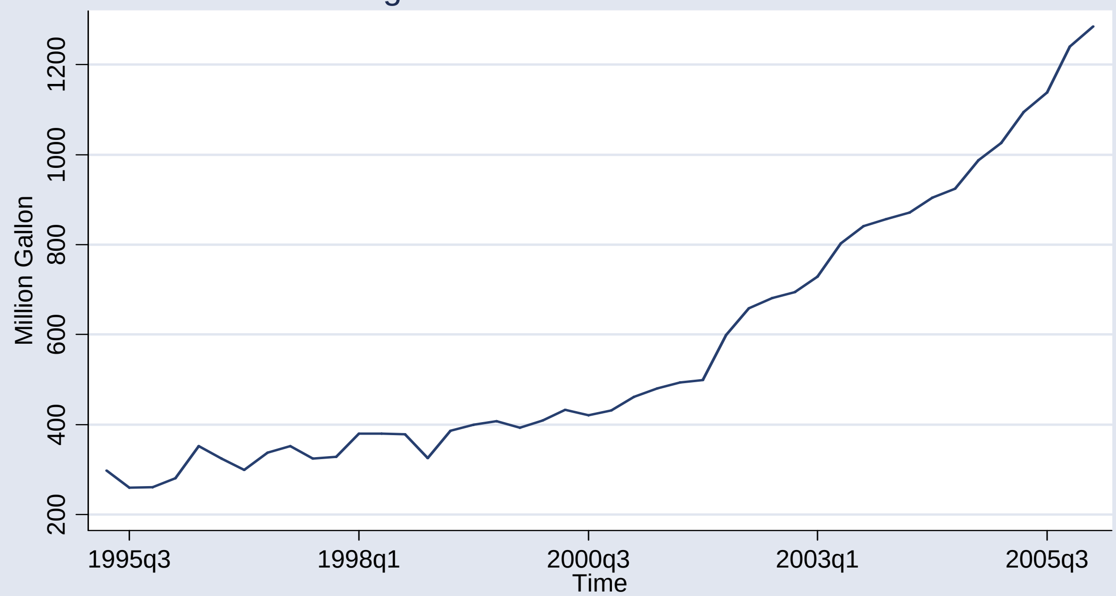
This suggests that a 1% increase in ethanol production causes a 0.16% increase in the corn price in short run, *ceteris paribus*. Current ethanol production is around 5 billion gallons per year and the USDA is projecting an average U.S. farm level corn price of $3.20 per bushel in the 2006/2007 marketing year. If ethanol production increases by 100%, to 10 billion gallons next year, then the corn price will increase by 16%, which is about 51cents per bushel relative to the current USDA price forecast, *ceteris paribus*. While this is a significant increase, it is substantially less than the doubling of the corn price in the 2006/2007 marketing year. As a result, while ethanol production has a significant and positive impact on corn price, it does not fully explain price level changes in the 2006/2007 marketing year.

Conclusions

A system of five equations representing the U.S. corn market is estimated by 3SLS. Results show that increasing ethanol production has a significant impact on the national average U.S. corn price. The positive price change is consistent with previous research. However, in contrast to what is written in much of the popular press, results do not suggest the extremely high corn prices in spring of 2007 can be completely attributed to ethanol. Despite this, corn growers in the U.S. have benefited in the form of higher prices as a result of growth in the ethanol industry.

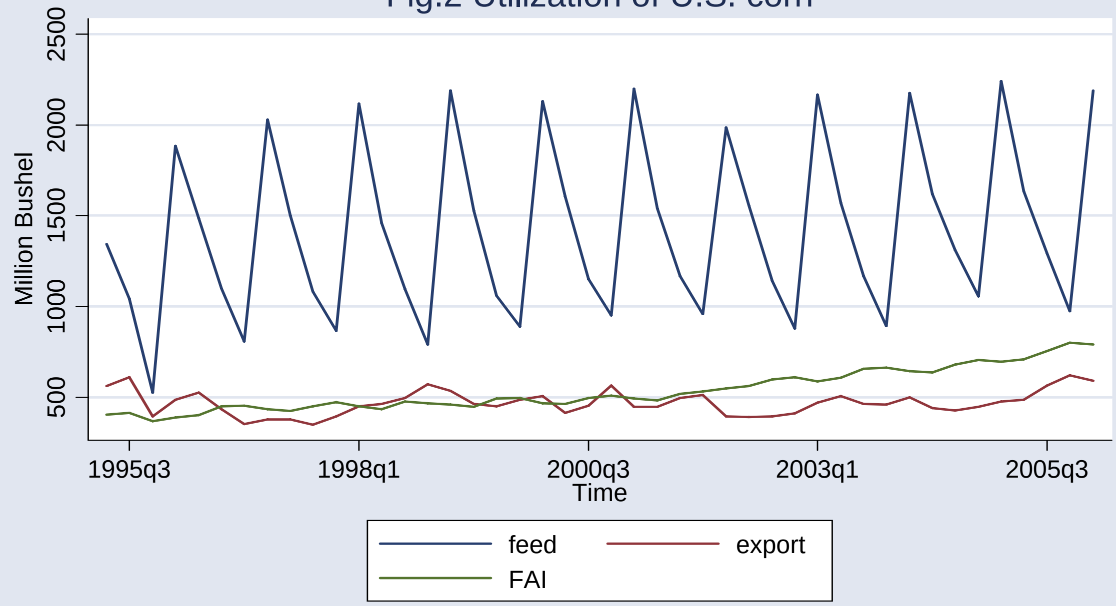
To more fully understand the overall impact of ethanol on corn prices, future research includes measuring interaction across other commodity markets, and combining the structural simultaneous equation models presented here with time series models. In addition, long run effects of ethanol production on grain, livestock and gasoline market should be investigated by introducing dynamics.

Fig.1 Ethanol Production in U.S.



Source : EIA and author's calculation

Fig.2 Utilization of U.S. corn



Source : USDA and author's calculation

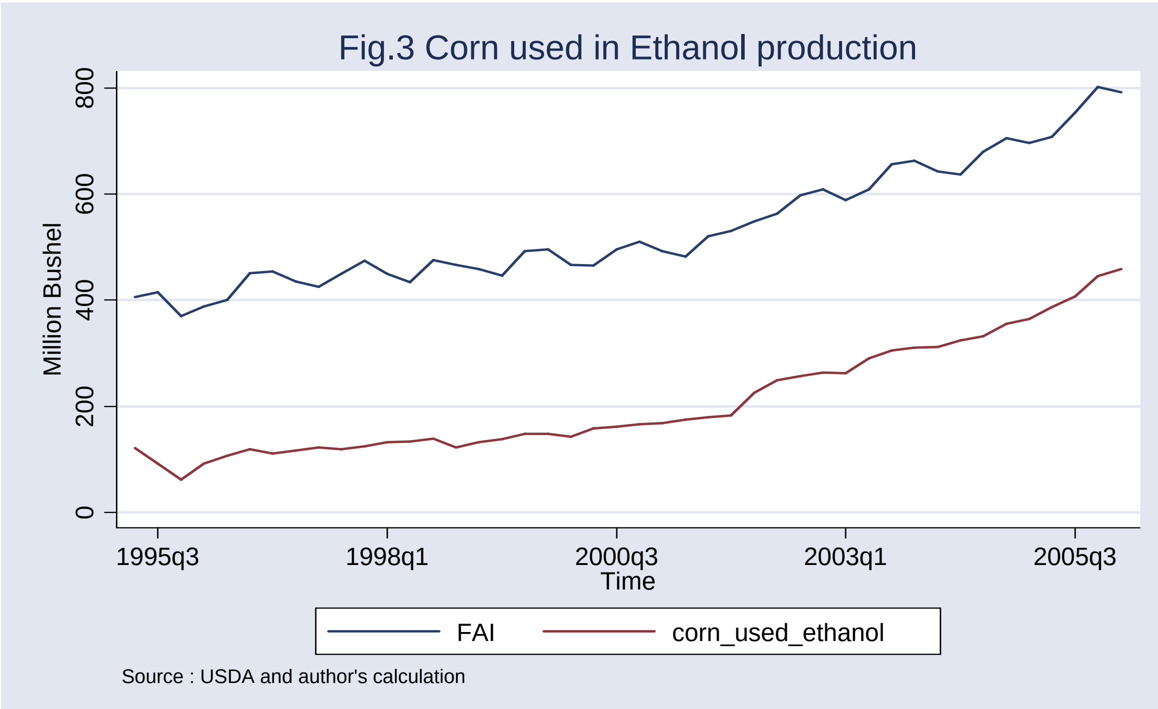


Fig.3 Corn used in Ethanol production

Source : USDA and author's calculation

Table 1 : Results of estimation

	I. Base (5 endogenous)		II. Alternative (4 endogenous)	
	RMSE*	R^2	RMSE	R^2
Supply	.0448	.96	.0484	.96
Feed	.0224	.98	.0227	.98
FAI	.0103	.99	.0103	.99
Export	.0447	.47	.0431	.50
Price	.0301	.88	.0297	.88

*: Root Mean Squared Error

Table 2 : Results of estimation

		I. Base (5 endogenous)		II. Alternative (4 endogenous)	
		coef(s.e)	t_value	coef(s.e)	t_value
Price	const	3.4578(.6809)	5.08	1.8691(.6094)	3.07
	S_t	-1.1715(.1912)	-6.13	-1.0276(.1863)	-5.52
	F_t	.0868(.2573)	.34	.3683(.2946)	1.25
	EX_t	.2678(.0851)	3.14	.3434(.0904)	3.80
	FAI_t	.4470(.0843)	5.30	.3383(.0760)	4.45
	P_{t-1}^C	.3424(.0902)	3.79	.4914(.0799)	6.15
	D_1	.5941(.0902)	6.58	.4071(.0774)	5.26
	D_2	.4689(.0629)	7.45	.3443(.0529)	6.51
	D_3	.2810(.0358)	7.86	.2160(.0301)	7.18
Supply	const	3.1654(.7999)	3.96	2.3590(.9994)	2.36
	P_{t-1}^C	-.3885(.1272)	-3.06	-.2784(.1534)	-1.82
	R_{t-1}	-.0638(.0483)	-1.32	-.0536(.0597)	-.90
	S_{t-1}	.3524(.1413)	2.49	.4963(.1772)	2.80
	D_1	.6178(.0387)	15.95	.6523(.0471)	13.84
	D_2	.2688(.0441)	6.09	.2285(.0541)	4.22
	D_3	.1610(.0288)	5.59	.1391(.0341)	4.07

- continued

		I. Base (5 endogenous)		II. Alternative (4 endogenous)	
		coef(s.e)	t_value	coef(s.e)	t_value
Feed	const	-1.4863(1.6279)	-.91	-1.3384(1.6971)	-.79
	P_t^C	-.2978(.0824)	-3.61	-.3968(.0832)	-4.77
	P_t^{sm}	.1813(.0536)	3.38	.2316(.0559)	4.14
	B_t	.1999(.1040)	1.92	.2514(.1065)	2.36
	COF_t	.3885(.1906)	2.04	.2425(.1961)	1.24
	H_t	.4423(.3298)	1.34	.5020(.3514)	1.43
	D_1	.3851(.0107)	36.09	.3887(.0107)	36.19
	D_2	.2410(.0144)	16.72	.2509(.0147)	17.05
	D_3	.1212(.0122)	9.93	.1287(.0124)	10.36
FAI	const	18.8002(10.5341)	1.78	15.7522(10.5341)	1.50
	P_t^C	-.0753(.0307)	-2.45	-.0642(.0300)	-2.14
	Eth_t	.4016(.0555)	7.23	.3995(.0559)	7.15
	Pop_t	-6.9923(4.2911)	-1.63	-5.7460(4.2910)	-1.34
	T_t	.0081(.0054)	1.50	.0068(.0054)	1.25
	D_1	-.0333(.0063)	-5.27	-.0316(.0063)	-5.03
	D_2	-.0220(.0119)	-1.84	-.0247(.0120)	-2.06
	D_3	.0048(.0072)	.67	.0032(.0072)	.45
Export	const	5.0533(2.4389)	2.07	3.8144(2.5246)	1.51
	P_t^C	-.2644(.1318)	-2.01	-.3211(.1327)	-2.42
	EX_{t-1}	.6059(.1071)	5.66	.4763(.1145)	4.16
	W_t^{row}	-1.0416(.3420)	-3.05	-.8595(.3584)	-2.40
	DX_t	-.2319(.3240)	-.72	-.3063(.3332)	-.92
	GDP_t	.3632(.2820)	1.29	.6154(.3005)	2.05
	D_1	-.0028(.0185)	-.15	-.0033(.0185)	-.18
	D_2	-.0214(.0184)	-1.16	-.0188(.0184)	-.1.02
	D_3	-.0027(.0184)	-.15	-.0012(.0184)	-.06

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