Impact of Ethanol Policies on Livestock Production in the United States

By

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1. Introduction

Even though the federal legislation for ethanol has been around since the Energy Tax Act of 1978, the recent ethanol boom has been shaped by legislation at the state as well as the federal levels (Collins, 2008). The recent increase in demand for biofuel derived from agricultural products has created interest in the effects of biofuel production on U.S. agriculture. Specifically, livestock producers have seen the impacts of ethanol production on their feed sources. Earlier research has examined the implications of ethanol policy on crop and livestock independently using simulation, statistical and/or mathematical models. Here, we are linking the crop and livestock model using comparative statics supported by statistical model to evaluate the direct and indirect impacts of ethanol policy on livestock. This paper analyzes the effects of ethanol policy on livestock production.

A recent boom in the ethanol industry has contributed to the rise in feed prices and their respective volatilities (Becker, 2008). Ethanol production's role in increasing feed prices stems from the fact that the majority of ethanol is produced from corn, which is the leading source of feed for livestock in the United States. Approximately 95% of the feedstock for ethanol production is corn with the remaining 5% consisting of grain sorghum, barley, wheat, cheese whey, and potatoes (Yacobucci, 2008). Therefore, the demand for corn by ethanol producers increases when there is an increase in demand for ethanol. Because of the demand for corn by the ethanol industry, livestock producers face greater competition for their major feed source, corn. However, production of ethanol yields by-products such as the wet distiller's grains

(WDG), dried distiller's grains (DDG) and condensed distiller's soluble (CDS) which can be fed to livestock, and may, at least partially, offset the diminishing supply of feed corn. However, these ethanol by-products have limitations and difficulties of their own (Fabiosa, 2008).

Objectives of this study are twofold: (1) to develop a theoretical model to explain and analyze the relationship of ethanol policy and livestock production, and (2) to empirically test the indirect and direct effects of ethanol policy on cattle production utilizing an econometric model. The results of this study may give greater knowledge to policy makers, who can be better informed with respect to the secondary effects of ethanol legislation. Understanding the effects of ethanol policies on all markets is important in lawmakers' decision-making process.

Section 2 offers additional background information related to ethanol production, biofuel policy, feed supply, and livestock production along with a comprehensive review of literature related to the objectives of this study. Section 3 includes a theoretical model, while section 4 includes empirical/econometric model that explain the relationship between ethanol policy and livestock production. Section 5 consists of the results of the econometric estimation. Section 6 provides conclusions and implications of the research.

2. Ethanol, Corn and Livestock Intertwined: Background

Utilization of corn as an input in ethanol production has risen because of the expanding ethanol industry. Since corn is the main feedstock in ethanol production, its demand by ethanol plants has increased with the increase in demand for ethanol (USDA-ERS, 2009a, 2009b). The ethanol plants demand for corn gradually increased between the market year 1990 and market year 1998. It was an increase of 176.7 million bushels or 50.6% during that eight-year period. In 1999, the demand for corn by ethanol plants began to expand rapidly. From market year 1999 to market year 2007, the demand for corn by ethanol plants increased by 2,483.45 million

bushels or 439%. The demand for corn by ethanol plants will continue to rise as long as corn is a major feedstock in the production of ethanol. Projections by the USDA-ERS (2009 a, 2009b) indicate the utilization of corn for ethanol will continue to increase but at a slower rate, which is due to the federal mandate continuing at a slower rate with respect to corn based ethanol.

Livestock producers are faced with increased competition from the ethanol industry for their leading source of feed, corn. However, the increased ethanol production has increased the production of distillers' grains (DG), which is another source of feed for livestock (Renewable Fuels Association, 2008; Tokgoz *et al.*, 2007; USDA-ERS, 2009a). Yearly DG production increased from 2,190,311 thousand short tons in market year 1999 to 21,534,786 thousand short tons in market year 2007, which is an increase of 19,344,475 short tons or 883%. The yearly amount of corn used for livestock feed has also generally increased throughout the period. However, the amount of corn used for livestock feed has not risen as drastically, in relative percentage terms, as the production of DG.

DG's ability to be substituted for corn in livestock feed rations helps alleviate the livestock industry's problem of increased competition for corn from the ethanol industry. The protein level of DG is less than oilseed meals and greater than feed grains such as corn. The energy content of DG is similar to feed grain levels. However, DGs are not all created equal, meaning there is greater inconsistency in the composition of DG compared to corn. For instance, the production process of converting corn into ethanol magnifies any corn nutrient variability by three fold in the final product, DG (Fabiosa, 2008; Erickson *et al.*, 2007). Furthermore, quality and content of DG can vary between batches of ethanol production as processors make adjustments to optimize production (Mathews and McConnell, 2009). Greater variation of DG quality and content can occur between plants because of different feedstock sources.

Maximum inclusion rates of DG in livestock rations vary by livestock species and production stage. The maximum inclusion rates are set to maintain diet quality, nutrient requirements, and animal health. The optimal economic inclusion rate of DG depends on its price, livestock performance, distance from the ethanol plant, and corn price (Erickson *et al.*, 2007). Results of the study indicate the optimal inclusion rate for DDGS is 10%-35% depending on relative feed costs and transportation costs. With respect to WDGS, the inclusion rates are higher, 35% to 48%, depending on relative feed and transportation costs (Jones *et al.*, 2007). The study conducted by Benson *et al.* (2005) concluded that finishing beef cattle performance was maximized at an inclusion rate of 25% based on carcass traits and performance levels while Loy (2006) suggested the inclusion rates of 40% to 50% in beef cattle feed rations being appropriate.

Poultry and pork are non-ruminants which limits the use of DG in their feed rations because the fiber found in DG is less digestible. Also, other nutritional factors such as levels of sulfur, phosphorus, or fat play a role in deciding the inclusion rate of DG in livestock feed rations (Clemens and Babcock, 2008; Schingoethe, 2007; Tjardes and Wright, 2002). There are multiple recommended inclusion levels for each livestock species. However, beef cattle tend to have the largest inclusion level, with pork and poultry having the lowest.

Transportation of DG from the processing plant to the livestock feeding operation is another challenge faced by the industry. The moisture content of the DG products can cause spoiling and problems with shipping and handling the products. Generally, low moisture content products are easier to ship than high moisture products. Therefore, DDG are generally easier to ship than WDG (Mathews and McConnell, 2009).

The use of DG in the feed ration of livestock is also dependent on relative price. The price of DG has generally been higher, compared to the price of corn through the period of quarter one of market year 1990 to quarter four of market year 2005 (USDA-ERS 2009a). During that period, the price of DG was lower than corn for only eight out of the 64 quarters. The price of DG beginning in the first quarter of market year 2006 to present has been relatively low in comparison to the price of corn. This decline in the relative price has allowed for greater substitution of DG for corn in livestock feed rations.

Multiple studies have forecasted the impact of biofuel policy on agriculture and energy products. The studies first set up a baseline forecast, then compared forecasts of different scenarios to the baseline. A non-exhaustive list of studies that have used this method in some fashion follows.

The study on the European Union indicated that an increase in the production of ethanol, because of a rise in oil prices, would increase DG production and corn prices while decreasing DG prices (Tokgoz, 2009). Tokgoz *et al.* (2008) took it one-step further in their U.S. study by including the impacts on beef production and prices. They found an increase in oil prices will increase corn prices, DG prices, DG production, and beef prices along with a decrease in corn used as feed and beef production. Their results were different compared to the European Union study because the price of DG increases in the U.S. study. The three studies, which studied the removal of policy programs, had one conflicting result, the production of beef. However, they had similar results in the case of corn used as feed, corn prices, DG prices, and beef prices (McPhail and Babcock, 2008; Hayes *et al.*, 2009; Tokgoz *et al.*, 2007). The studies by Peters *et al.*, (2009) and Kruse *et al.*, (2007) found an increase in demand and production of ethanol yields a decline in the production of beef. However, the study that modeled increasing ethanol

production to 12, 15, and 20 billion gallons found that beef production would increase (Economic Research Service and Office of the Chief Economist, 2007). The different results could be attributed to the difference in predicting DG's role in providing feed to livestock.

One of the first studies conducted to forecast the impacts of ethanol policy on agriculture products was done by Elobeid *et al.*, (2006). The study estimated the impacts of different scenarios on the amount of corn used for feed compared to a baseline. Livestock producers' profits rely heavily on the availability and price of their major input, feed. Impacts on corn feed use are positive under these five scenarios: the price of crude oil declines, the ethanol tariff is removed, the ethanol tariff along with the blenders' credits are removed, the DG price declines, and the price of natural gas increases. Natural gas is a major variable cost in the production of ethanol. The impacts are negative under these four scenarios: the crude oil price increases, the DG price increases, corn imports is zero, and the price of natural gas declines. According to the authors, ethanol policy will increase feed costs for livestock producers, which will cause some producers to exit the industry (Elobeid *et al.*, 2006).

Analysis conducted by Taheripour *et al.*, (2008) examines the impact of not including biofuel by-products in the forecasts of agricultural prices and production under different policy scenarios. The study compared forecasts for the year 2015 with and without biofuel by-products. Results for the livestock sector indicate production will decline whether or not DG is included in the forecast. However, the decline in livestock production is smaller with the inclusion of biofuel by-products in the model. By-products of biofuel production, especially DG, are important in supplying feed to livestock (Taheripour *et al.*, 2008).

3. Comparative statics theoretical model

The theoretical model begins with an ethanol model containing one input and two outputs, followed by a livestock model containing two inputs and one output. General theoretical framework for each individual model was adopted from Gardner (1975, 1987, 2002). However, the combination of the two models representing the theoretical framework for this study is a novelty developed here enabling us to link and to track fully the policy impact on a sector that has not been targeted by policy makers directly. The theoretical model contains a general livestock model that can be adapted for use as a cattle model. Corn is the sole input for the ethanol model and a joint input in the livestock model with distillers' grains (DG) being the other input. Outputs of the ethanol model are ethanol and DG, with the assumption that they are joint products produced in fixed proportion.

Comparative Statics - Ethanol Model

The ethanol model is defined by six equations:

$$
\begin{aligned}
x &= D_1\left(P_x, Z_1\right) \\
y &= D_2\left(P_y, Z_2\right) \\
a &= g\left(P_a, Z_3\right) \\
a &= \gamma_x * x \qquad\qquad \textit{Production relation of corn and ethanol} \\
a &= \gamma_y * y \qquad\qquad \textit{Production relation of corn and DG} \\
P_a &= \left(\frac{1}{\gamma_x}\right) * P_x + \left(\frac{1}{\gamma_y}\right) * P_y - P_s
\end{aligned}
$$

(1)

where x is demand for ethanol; P_x is price of ethanol (dollars/unit of ethanol); Z_1 is shift variable (e.g., some government policy affecting ethanol); y is demand for DG; P_y is price of DG (dollars/unit of DG); Z_2 is shift variable (e.g., some government policy affecting DG); a is supply of corn; P_a is price of corn (dollars/unit of corn); Z_3 is shift variable (e.g., some government policy variable affecting corn); P_s is processing service (dollars/unit of corn); and,

$$\gamma_x = \frac{tons\ of\ grain}{tons\ of\ ethanol} = \frac{a}{x} \ and \ \gamma_y = \frac{tons\ of\ grain}{tons\ of\ DG} = \frac{a}{y}.$$

To examine the effects of an exogenous change, the six equations are totally differentiated and then converted into elasticities. This can be represented as

$$Ex^d = \eta_x\, EP_x + \eta_z\, EP_z$$
$$Ex^d = \eta_x\, EP_x + \eta_z\, EP_z$$
$$Ey^d = \eta_y EP_y + \eta_{yZ_2} EZ_2$$

(2) $\quad Ea^s = e_a EP_a + e_{aZ_3} EZ_3$

$$Ea = Ex$$
$$Ea = Ey$$
$$EP_a = K_x EP_x + K_y EP_y$$

Where: $\quad \dfrac{dx}{x} = Ex^d \qquad \left(\dfrac{P_X}{x}\dfrac{\delta D_1}{\delta P_x}\right) = \eta_x \qquad \dfrac{dP_X}{P_X} = EP_x \qquad \left(\dfrac{Z_1}{x}\dfrac{\delta D_1}{\delta Z_1}\right) = \eta_{xZ_1} \qquad \dfrac{dZ_1}{Z_1} = EZ_1$

Further note that η_x and η_y are the own-price elasticities of demand for ethanol and DDG, respectively; e_a is the elasticity of supply of corn; K_x and K_y are the shares of the value of 'a' (corn) accounted for by ethanol and DG; and η_{XZ_1} and η_{XZ_2} and η_{aZ_3} are partial elasticities with respect to exogenous variables.

Equation (2) can be represented in matrix form as the following[2]:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & -\eta_x & 0 \\ 0 & 0 & 1 & 0 & 0 & -\eta_y \\ 1 & 0 & 0 & -e_a & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -K_x & -K_y \end{bmatrix} * \begin{bmatrix} Ea \\ Ex \\ Ey \\ EP_a \\ EP_x \\ EP_y \end{bmatrix} = \begin{bmatrix} \eta_{xZ_1} EZ_1 \\ \eta_{yZ_2} EZ_2 \\ e_{aZ_3} EZ_3 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

It can now be assumed that the system of equations is shocked by a government policy. For example, the U.S. government utilizes a policy to increase the demand for ethanol to encourage less dependence on oil imports, environment protection, etc. This policy is represented by an

increase of Z_1 or $EZ_1 > 0$ implying that the demand for ethanol shifts to the right. Assuming EZ_2 = 0 and $EZ_3 = 0$, the system of equations can be simplified as following:

$$
\begin{bmatrix} 1 & -\eta_x & 0 \\ 1 & 0 & -\eta_y \\ 1 & 0 & -e_a K_y \end{bmatrix} * \begin{bmatrix} \dfrac{EP_a}{EZ_1} \\ \dfrac{EP_x}{EZ_1} \\ \dfrac{EP_y}{EZ_1} \end{bmatrix} = \begin{bmatrix} \eta_{xZ_1} \\ 0 \\ 0 \end{bmatrix}
$$

Solving it by Cramer's Rule:

(3) $\quad \dfrac{EP_x}{EZ_1} = \dfrac{\overset{(+)\ (-)}{-\eta_{xZ_1} \eta_y} + \overset{(+)\ (+)\ (+)}{\eta_{xZ_1} e_a K_y}}{\underset{(+)}{D}} > 0$, implying that the price of ethanol must increase.

$Note: D = \left\{ \overset{(-)(-)}{\eta_x \eta_y} - \overset{(+)}{e_a} \left(\overset{(+)\ (-)}{K_x \eta_y} + \overset{(+)\ (-)}{K_y \eta_x} \right) \right\} > 0$

(4) $\quad \dfrac{EP_y}{EZ_1} = \dfrac{\overset{(+)\ (+)\ (+)}{-\eta_{xZ_1} e_a K_x}}{\underset{(+)}{D}} < 0$, implying that the price of DG must fall.

From the last equation in equation (2)

$$\dfrac{EP_a}{EZ_1} = K_x * \dfrac{EP_x}{EZ_1} + K_y * \dfrac{EP_y}{EZ_1}$$

(5) $\quad = \dfrac{K_x \left[-\eta_{xZ_1} \eta_y + \eta_{xZ_1} e_a K_y \right] - K_y \eta_{xZ_1} * e_a K_x}{D}$, implying that the price of corn must

$\quad = \dfrac{\overset{(+)\ (+)\ (-)}{-K_x \eta_{xZ_1} \eta_y}}{\underset{(+)}{D}} > 0$

increase.

Implications of an increase in demand for ethanol created by a governmental policy are an increase in the price of ethanol and the price of corn, with a decrease in the price of DG.

Comparative Statics - Livestock Model

The livestock model has two inputs and one output where the two inputs are DG and corn, and

the only output is livestock. Then, six equations represent the livestock model.

(6)
$$x^s = f(a^d, b^d) \qquad \text{Livestock Industry Production}$$
$$P_a = P_x * f_a(a^d, b^d) \qquad \text{Demand for corn}$$
$$P_b = P_x * f_b(a^d, b^d) \qquad \text{Demand for DG}$$
$$a^s = g(P_a - T_a) \qquad \text{Supply of corn}$$
$$b^s = h(P_b - T_b) \qquad \text{Supply of DG}$$
$$x^d = D(P_x) \qquad \text{Demand for livestock}$$

Where the second and third equations in equation (6) come from the first order condition (FOC)

of profit maximization, and a^d = quantity of corn demanded; b^d = quantity of DG demanded; f_a

= Partial derivative with respect to 'a' (corn); P_x = Price of livestock; P_a = Price of corn; f_b =

Partial derivative with respect to 'b' (DG); P_x = Price of livestock; and P_b = Price of DG.

Assumptions of the model are as following: (a) Output markets are competitive; (b) Input

markets are competitive; (c) Producers maximize profits; (d) All firms are identical and only one

least cost technology exists. The least cost technology can be represented by a concave twice-

differentiable production function, which generates the usual U shaped average cost curve for

each firm; (e) Supply curves slope up and demand curves slope down; (f) T_a is an indirect tax

per unit of input 'a' and when $T_a < 0$ it becomes and indirect subsidy. From the Joint Products

Model that ethanol subsidy causes corn prices to increase and DG prices to decrease so that

$$T_a = \frac{\delta P_a}{\delta Z_1} \Rightarrow \text{ indirect subsidy for corn and } T_b = \frac{\delta P_b}{\delta Z_1} \Rightarrow \text{ indirect tax for DG.}$$

Equation (6) is then totally differentiated around $T_a = 0$ and $T_b = 0$.

$$Ex^s - k_a E_a - k_b E_b = 0$$

$$-EP_x + \frac{k_b}{\varphi} E_a - \frac{k_b}{\varphi} E_b + EP_a = 0$$

$$-EP_x - \frac{k_a}{\varphi} E_a + \frac{k_a}{\varphi} E_b + EP_b = 0$$

(7)

$$\frac{1}{e_a} E_a - EP_a = ET_a$$

$$\frac{-1}{e_b} E_b + EP_b = ET_b$$

$$Ex - \eta EP_x = 0$$

where η is the elasticity of demand for livestock, k_a is corn's share of total cost, and k_b is DG's share of total cost. Also, note from constant returns of scale:

$$\varphi = \frac{f_a f_b}{f_{ab} * f(a,b)} > 0$$

The system of equations is presented in matrix form below:

$$
\begin{bmatrix}
1 & 0 & -k_a & -k_b & 0 & 0 \\
0 & -1 & \frac{k_b}{\varphi} & \frac{-k_b}{\varphi} & 1 & 0 \\
0 & -1 & \frac{-k_a}{\varphi} & \frac{k_a}{\varphi} & 0 & 1 \\
0 & 0 & \frac{1}{e_a} & 0 & -1 & 0 \\
0 & 0 & 0 & \frac{-1}{e_b} & 0 & 1 \\
1 & -\eta & 0 & 0 & 0 & 0
\end{bmatrix}
*
\begin{bmatrix}
Ex \\ EP_x \\ Ea \\ Eb \\ EP_a \\ EP_b
\end{bmatrix}
=
\begin{bmatrix}
0 \\ 0 \\ 0 \\ ET_a \\ ET_b \\ 0
\end{bmatrix}
$$

To analyze a change in T_a, indirect tax on corn, all the variables are divided by ET_a.

(8) $$\frac{EP_x}{ET_a} = \frac{\overset{(+)(+)(+)\quad(+)}{k_a e_a (e_b + \varphi)}}{\underset{(+)}{D}} > 0$$

Where $D = \overset{(+)(+)}{e_a e_b} - \eta(\overset{(-)}{\varphi} + \overset{(+)}{k_a e_b} + \overset{(+)(+)}{k_b e_a}) + \varphi(\overset{(+)(+)(+)}{k_a e_a} + \overset{(+)(+)}{k_a e_b}) > 0$

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(9) $\quad \dfrac{Ex}{ET_a} = \dfrac{\overset{(+)\,(-)\,(+)\,(+)\quad(+)}{k_a\;\eta\;e_a(e_b + \varphi)}}{\underset{(+)}{D}} < 0$

(10) $\quad \dfrac{EP_a}{ET_a} = \dfrac{\overset{(+)\,(+)\quad(+)\,(+)\quad(+)\,(-)}{e_a(e_b + k_a\;\varphi - k_b\;\eta)}}{\underset{(+)}{D}} > 0$

(11) $\quad \dfrac{Ea}{ET_a} = \dfrac{\overset{(+)\,(+)\,(-)\quad(+)\;\;(+)\,(+)\quad(+)\,(-)}{e_a\;\varphi\;\eta - e_b(k_b\;\varphi - k_a\;\eta)}}{\underset{(+)}{D}} < 0$

Dividing equation (9) by equation (10) calculates the effects of a change in price of corn on the production of livestock, which is represented by Ex/EP_a in equation (12). In addition, dividing equation (9) by equation (11) calculates the effects of a change in the quantity of corn on the production of livestock, which is represented by Ex/Ea in equation (13).

(12) $\quad \dfrac{Ex}{EP_a} = \dfrac{\overset{(+)\,(-)\,(+)\quad(+)}{k_a\;\eta\,(e_b + \varphi)}}{\underset{(+)\;\;\;(+)\quad(+)\,(-)}{e_b + k_a - k_b\;\eta}} < 0$

(13) $\quad \dfrac{Ex}{Ea} = \dfrac{\overset{(+)\,(-)\,(+)\,(+)\quad(+)}{k_a\;\eta\;e_a(e_b + \varphi)}}{\underset{(+)\,(+)\,(-)\quad(+)\;\;(+)\,(+)\quad(+)\,(-)}{e_a\;\varphi\;\eta - e_b(k_b\;\varphi - k_a\;\eta)}} > 0$

To analyze a change in T_b, indirect tax on DG, all the variables are divided by ET_b.

(14) $\quad \dfrac{EP_x}{ET_b} = \dfrac{\overset{(+)\,(+)\,(+)\quad(+)}{k_b\;e_b(e_a + \varphi)}}{\underset{(+)}{D}} > 0$

(15) $\quad \dfrac{Ex}{ET_b} = \dfrac{\overset{(+)\,(-)\,(+)\,(+)\quad(+)}{k_b\;\eta\;e_b(e_a + \varphi)}}{\underset{(+)}{D}} < 0$

(16) $\quad \dfrac{EP_b}{ET_b} = \dfrac{\overset{(+)\;\;(+)\quad(+)\,(+)\quad(+)\,(-)}{e_b(e_a + k_b\;\varphi - k_a\;\eta)}}{\underset{(+)}{D}} > 0$

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(17)
$$\frac{Eb}{ET_b} = \frac{\overset{(+)(+)(-)}{e_b\,\varphi\,\eta} - \overset{(+)}{e_a}(\overset{(+)(+)}{k_a\,\varphi} - \overset{(+)(-)}{k_b\,\eta})}{\underset{(+)}{D}} < 0$$

Dividing equation (15) by equation (16) calculates the effects of a change in price of DG on the production of livestock, which is represented by Ex/EP_b in equation (18). In addition, dividing equation (15) by equation (17) calculates the effects of a change in the quantity of DG on the production of livestock, which is represented by Ex/Eb in equation (19).

(18)
$$\frac{Ex}{EP_b} = \frac{\overset{(+)(-)}{k_b\,\eta}\,\overset{(+)}{(e_a}+\overset{(+)}{\varphi)}}{\underset{(+)}{e_a} + \underset{(+)}{k_b} - \underset{(+)(-)}{k_a\,\eta}} < 0$$

(19)
$$\frac{Ex}{Eb} = \frac{\overset{(+)(-)(+)}{k_b\,\eta\,e_b}\overset{(+)}{(e_a}+\overset{(+)}{\varphi)}}{\underset{(+)(+)(-)}{e_b\,\varphi\,\eta} - \underset{(+)}{e_a}(\underset{(+)(+)}{k_a\,\varphi} - \underset{(+)(-)}{k_b\,\eta})} > 0$$

Results from the theoretical model indicate that an increase in ethanol demand from a government policy will increase the price of corn and decrease the price of DG. The increase in price of corn because of an ethanol policy, represented by T_a, will cause the production of livestock to decrease and the price of livestock to increase. However, the decrease in price of DG because of the ethanol policy has an opposite effect on livestock production and price. The decline in DG price, represented by T_b, will cause the production of livestock to increase and the price of livestock to decrease. The overall total indirect effect of an ethanol policy on livestock production and price depends on the size of k_a and k_b because of the opposite effects ethanol policy has on DG and corn.

While the general theoretical model consists of an ethanol model and a livestock model, an empirical cattle model was developed to evaluate the direct and indirect effects of ethanol policy on the production of cattle using two inputs, corn and DG. The cattle model analyzes the

effects of ethanol policy through two feed inputs, corn and DG. Direct effects of ethanol policy

are on corn and DG quantity available for cattle producers. The availability of corn and DG to

cattle producers affects the quantity of cattle produced. Therefore, indirect effects of ethanol

policy on cattle production are transferred through the feed sources, corn and DG. The model

contains three endogenous variables, quantity of cattle produced, quantity of corn, and quantity

of distillers' grains. Because of the identification issue, the three equations should be estimated

using a Simultaneous Equation Estimation in order to have unbiased and efficient coefficients.

Due to the assumption of perfect competition in the empirical model, demand equals supply.

4. Data and the Empirical/Econometric Model

The data used in the estimation are reported quarterly with a proportion of the data collected

monthly and aggregated into quarterly data. Given variable constraints, data contains 75

observations beginning with the first quarter of the 1990 crop year and ending with the third

quarter of the 2008 crop year. Quarters are based on the crop year for corn, which begins on

September 1 and ends on August 31. Quarter 1 is September to November, quarter 2 is

December to February, quarter 3 is March to May, and quarter 4 is June to August.

Notation in the empirical model is as following: t - Subscript used to indicate time period;

i - Subscript used to indicate the independent variable number; β_i - Coefficient used to represent

the ith independent variable; $cornq_t$ - Corn quantity in time period t; dgq_t - Distillers' grains

quantity in time period t; $catq_t$ - Cattle quantity in time period t; $cornp_t$ - Corn price in time

period t; $ethp_t$ - Ethanol price in time period t; dgp_t - Distillers' grains price in time period t

rfs_t - Dummy variable representing the Renewable Fuels Standard in time period t; $qt2_t$ - Dummy

variable representing quarter two in time period t; $qt3_t$ - Dummy variable representing quarter

three in time period t; $qt4_t$ - Dummy variable representing quarter four in time period t; $time_t$ -

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Arbitrary variable representing the time period for time period t; log(ρ) - Logarithmic transformation of variable ρ.

Data for the quantity of cattle produced were taken from the "Livestock Marketing Information Center" or LMIC, (http://www.lmic.info/). The data were accessed through the "Member's Only" section under the file entitled "catsltr." The total federally inspected beef slaughter was used to represent cattle quantity, which is in millions of pounds. The data are collected by month and aggregated into quarters. While the data on total cattle quantity is not available at quarterly frequencies for the period under consideration, the correlation between the total federally inspected beef slaughter quantity and total cattle quantity is positive and very high hence the first can serve as a proxy for the second.

The price of dried distillers' grains was collected from two areas of the United States Department of Agriculture: the Economic Research Service (ERS) and the Agriculture Marketing Service (AMS). The price of DDG collected was used to represent all distillers' grains prices. The price of DG is in dollars per short ton and the data are retrieved from the Lawrenceburg, Indiana, site because the site maximized the number of observations. Data are collected by month before being averaged into quarters. Data for DG price can be located through the ERS feed grains database query along with the AMS feedstuff market report query, ERS: (http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx) and AMS: (http://marketnews.usda.gov/portal/lg).

Corn quantity is collected from the ERS: feed grains database query using total supply of corn and Chicago market price of corn (http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx). Corn quantity is reported

in millions of bushels and corn price is dollars per bushel. Both sets of data were collected quarterly.

The ethanol prices were collected monthly as the average Free on Board (FOB) rack price for Omaha, Nebraska, in dollars per gallon. FOB is the price received at loading and rack price is otherwise known as the wholesale price. The monthly data are averaged into quarterly data. Ethanol price data were collected from the Nebraska Government Website: Ethanol and Unleaded Gasoline Average Rack Prices (http://www.neo.ne.gov/statshtml/66.html).

DG quantity was calculated using multiple data sources. To begin, annual data of ethanol produced from dry mill and wet mill facilities were collected from the Renewable Fuels Association, (http://www.ethanolrfa.org/). The data were then used to calculate the percentage of ethanol produced from dry mills by year. Quarterly data on the bushels of corn used for the production of ethanol were collected from the ERS feed grains database query, (http://www.ers.usda.gov/data/feedgrains/FeedGrainsQueriable.aspx). The quarterly bushels of corn used in the dry mill process to produce ethanol was calculated by taking the yearly percentage of dry mill ethanol production multiplied by the quarterly bushels of corn used for the production of ethanol. The recent increase in ethanol production has come from dry mill plants, while wet mill plants have remained steady in their production of ethanol. Therefore, wet mill by-products, corn gluten feed, and corn gluten meal, are not considered in the model. The quarterly bushels of corn used in dry mill ethanol plants are multiplied by 17 pounds per bushel to calculate the quarterly pounds of DG produced. According to Tokgoz *et al.* (2008), 17 pounds of distillers' grains are produced from one bushel of corn in a dry mill ethanol plant.

All variables except dummy variables and time were logarithmically transformed to remove any growth of the variance over time and to put the relationships in elasticity form

(Pindyck and Rubinfeld, 1997). Seasonality was a problem in both the cattle production and corn supply equations. To overcome the seasonality, dummy variables representing quarters two through four were added. Time trend variable was added to all three equations.

The three equations were estimated separately to determine the structure of the model. After adding the variables to overcome seasonality and trend, lagged exogenous variables were added to the equations. Determining the appropriate number of lags on the exogenous variables was done by minimizing the Schwartz criterion.[3] The equation for DG quantity was the only equation to receive a lagged variable based on the criterion used. The three equations were then tested for serial correlation using the Breusch-Godfrey Lagrange multiplier test. All three equations had serial correlation present up to eight lags. Lagged endogenous variables were added to the right-hand side of their respective equation to correct for serial correlation. The test for heteroskedasticity was conducted on all three equations utilizing the White test. The cattle quantity equation was found to have heteroskedasticity which was subsequently corrected in the estimation. The structure of the three equations is presented as:

$$
\begin{aligned}
log\left(catq_t\right) &= \beta_{-1} + \beta_2 log\left(cornq_t\right) + \beta_3 log\left(dgq_t\right) + \beta_4 qt2_t + \beta_5 qt3_t \\
&\quad + \beta_6 qt4_t + \beta_7 time_t + \beta_8 log\left(catq_{t-1}\right) + \varepsilon
\end{aligned}
$$

(20)
$$
\begin{aligned}
log\left(cornq_t\right) &= \beta_1 + \beta_2 log\left(cornp_t\right) + \beta_3 log\left(ethp_t\right) + \beta_4 rfs_t + \beta_5 qt2_t \\
&\quad + \beta_6 qt3_t + \beta_7 qt4_t + \beta_8 time_t + \beta_9 log\left(cornq_{t-1}\right) + \varepsilon
\end{aligned}
$$

$$
\begin{aligned}
log(dgq_t) &= \beta_1 + \beta_2 log\left(dgp_t\right) + \beta_3 log\left(ethp_t\right) + \beta_4 rfs_t + \beta_5 time_t \\
&\quad + \beta_6 log\left(ethp_{t-2}\right) + \beta_7 log(dgq_{t-1}) + \varepsilon
\end{aligned}
$$

The equations were estimated simultaneously using the weighted two-stage least squares method. The weighted part of the estimation corrected for heteroskedasticity detected in the equation for cattle quantity. In the estimation, the variables $catq_t$, $cornq_t$, and dgq_t were considered endogenous with the remaining being predetermined variables. Predetermined variables include exogenous variables and lagged endogenous variables. The results from the

simultaneous estimation equation give the indirect effects of ethanol policy on cattle production. To calculate the direct effects of ethanol policy on cattle production, the reduced form of the cattle quantity equation was estimated. The reduced form equation estimated cattle quantity utilizing all predetermined variables on the right hand side of the equation. The resulting equation is presented below.

(21) $log(catq_t) = \beta_1 + \beta_2 log(cornp_t) + \beta_3 log(dgp_t) + \beta_5 log(ethp_t) + \beta_6 rfs_t + \beta_7 qt2_t + \beta_8 qt3_t +$

$\beta_9 qt4_t + \beta_{10} time_t + \beta_{11} log(catq_{t-1}) + \beta_{12} log(cornq_{t-1}) + \beta_{13} log(dgq_{t-1}) + \beta_{13} log(ethp_{t-2}) + \varepsilon$

5. Results

Indirect Effects

The analysis of the indirect effects of ethanol policy on cattle quantity utilized the weighted two-stage least squares method for estimation. Results of the estimation are included in Table 1.

(INSERT TABLE 1 HERE)

The R-squared value for the cattle quantity equation is 0.894, which implies that 89.4% of the variation is explained by the explanatory variables. The adjusted R-squared value, which adjusts for sample size, is 0.883 in the cattle quantity equation. R-squared value and adjusted R-squared value for the corn quantity equation is 0.966 and 0.962, respectively. The R-squared value and adjusted R-squared value for the DG quantity equation is 0.989 and 0.988 respectively. High values of the R-squared indicate good fit of the model while very small differences between the R-squared and adjusted R-squared indicate good model specification.

The majority of the explanatory variables are significant at the 10% level or higher. Insignificant explanatory variables include the constant, DG quantity, quarter 2, and time in the cattle quantity equation. In the corn quantity equation, the only insignificant explanatory

variable is ethanol price. The results of the DG quantity equation show insignificant explanatory variables with respect to DG price, ethanol price, RFS, and two quarter lagged ethanol price.

The results are further reviewed considering the three equations in the estimation. In the DG quantity equation, the only significant variables are the constant, time, and one quarter lagged DG quantity. The coefficient on time being positive suggests DG quantity increases over time. The positive and significant coefficient of 0.909 on one quarter lagged DG quantity indicates that current DG quantity directly affects future DG quantity. The coefficient on DG price was insignificant in the equation, perhaps caused by ethanol plants only focusing on the price of ethanol when making production decisions.

The coefficients on the variables affecting corn quantity are analyzed next. The dummy variables representing three market-year quarters explain the seasonality of corn stocks. The coefficients on the quarter dummy variables are increasingly more negative from quarter 2 to quarter 4. Stocks of corn are the greatest during harvest, which is quarter 1, and the lowest right before harvest, which is quarter 4. After harvest, corn stocks are drawn down through the year until they are replenished by next year's harvest. The coefficients on the variables for time and one quarter lagged corn quantity were significant and positive indicating corn quantity increases through time and current quantity levels directly affect future quantity levels. The coefficient on the RFS dummy variable is significant and positive, which indicates the introduction of the Renewable Fuels Standard increased corn quantity. The coefficient on the corn price variable represents the own price elasticity of corn demand. The coefficient is -0.237 and significant. Interpretation of the coefficient can be as follows: a 10% increase in corn price will decrease the demand for corn by 2.37%.

Cattle quantity is a function of expected corn quantity and DG quantity along with seasonality variables and a variable representing one quarter lagged cattle quantity. Coefficients on the dummy variables for quarter 3 and 4 are significant suggesting there is seasonality in cattle quantity. The one quarter lagged cattle quantity variable has a positive and significant coefficient implying that current quarter cattle quantity directly affects the future cattle quantity. The coefficient on the expected corn quantity, which is calculated from its respectful equation, is significant and positive at 0.053. The positive coefficient indicates a direct relationship between corn quantity and cattle quantity, which is consistent with the result of the theoretical model. The corn quantity coefficient can be interpreted as follows: a 10% increase in expected corn quantity will increase cattle quantity by .53%. Therefore, the effect of a change in corn quantity on cattle quantity is relatively small. Expected DG quantity is insignificant in the cattle quantity equation. Insignificance of the coefficient on DG quantity may be due to the smaller amount of DG used as feed compared to corn.

Direct Effects

The analysis of the direct effects of ethanol policy on cattle quantity was estimated using the ordinary least squares method. The estimation was done in the reduced form equation, which was taken from the above simultaneous estimation equation. In this case, cattle quantity is a function of all predetermined variables. The results of the estimation are included in Table 2.

(INSERT TABLE 2 HERE)

The R-squared value for the reduced form equation is 0.915 indicating that 91.5% of the variation is explained by the explanatory variables while the adjusted R-squared value is 0.898 suggesting good model specification. The majority of the coefficients on the variables in the reduced form equation are significant. The significant coefficients on the dummy variables for

quarter 2 and 4, along with the time variable, suggest there is seasonality and trend with respect to cattle quantity. The significant and positive coefficient on the one quarter lagged quantity variable indicates that previous quarter quantity levels affect current quantity levels. Coefficients on variables for corn price, ethanol price, DG price, quarter 3, and two-quarter lagged ethanol price were insignificant. The coefficient on the variable for DG price indicates an inverse relationship between DG price and cattle production, which is the same result of the theoretical model. On the other hand, the coefficient on the variable for corn price indicates a direct relationship between corn price and cattle production, which is the opposite result of the theoretical model. However, both the coefficient on DG price and corn price are relatively small and insignificant at the 10% level.

The coefficient on the lagged variable of corn quantity is positive and significant, which implies an increase in the previous quarter's corn quantity will increase the current quarter's cattle quantity. This result makes sense since future cattle production decisions may be made from current feed availability. Surprisingly, the coefficient on the lagged variable of DG quantity has opposite results with it being significant and negative. The negative coefficient may well be valid because increased production of DG implies increased demand for corn from ethanol producers, which may decrease the availability of corn for feed and causing a drop in future cattle quantity. However, this reasoning is under the assumption that cattle producers utilize corn more than DG in their feed rations.

The positive and significant coefficient on the RFS dummy variable is interesting because it indicates cattle production has increased with respect to an ethanol policy. This result indicates there are direct effects of RFS on cattle production. The RFS increased demand for ethanol, which increased the demand for corn and increased the supply of DG. If the increase in

demand for corn by ethanol producers was met by an increase in the supply of corn, the availability of corn for feed would remain steady and the production of DG would increase. Because of the ability to substitute corn and DG in cattle feed rations, there would be greater availability of total feed, which may increase cattle production. The coefficient of the RFS dummy variable on corn quantity was also positive and significant in the simultaneous estimation equation. In addition to the direct effects of the RFS on cattle quantity, there are indirect effects of the RFS on cattle quantity via corn quantity.

The blenders' credit is represented through the ethanol price variable. The coefficient on the ethanol price variable is insignificant indicating there is no direct effect of blenders' credit on cattle production. This result coincides with policy makers intentions with respect to ethanol policy. The coefficients on ethanol price in the simultaneous estimation equation were all insignificant. However, this does not imply a similar conclusion of no indirect effects of blenders' credit on cattle production. Indirect effects of blenders' credit on cattle production follow several paths and are not limited to corn and DG quantity.

6. Conclusions and Implications

This study was conducted to analyze the direct and indirect effects of ethanol policy on livestock production. The relationships between corn, DG, ethanol, and livestock were explained throughout the study and specifically in the theoretical, empirical, and econometric models. Ethanol and DG are produced mainly from corn in semi-fixed proportions, while livestock production utilizes corn and DG as feed. Corn and DG are feed substitutes. Ethanol policy increases the demand for ethanol, which increases the demand for corn. The increased production of ethanol increases the production of DG. Cattle producers are faced with an increase in competition for corn and a greater supply of DG.

The theoretical model contains a general livestock model that can be adapted to different livestock species. Based off the theoretical model, an increase in demand for ethanol from an ethanol policy will increase corn prices and decrease DG prices. The overall effect of ethanol policy on livestock production is uncertain in the theoretical model because of the opposite effects policy has on DG and livestock prices. A decline in DG prices in the theoretical model may increase livestock production and decrease livestock prices. The opposite is true for an increase in corn prices creating a decline in cattle production and an increase in cattle prices.

Empirically, indirect effects of ethanol policy on cattle production were modeled using a system of three equations estimated simultaneously. The cattle production equation included two endogenous variables, corn quantity and DG quantity, along with predetermined variables. The corn quantity equation included exogenous variables for corn price, ethanol price, and RFS. The DG quantity equation was similar to the corn quantity equation with the inclusion of DG price instead of corn price. Both the corn quantity and DG quantity equations exhibited a positive time trend, and both the cattle quantity and corn quantity equations exhibited seasonality based on market year quarters. The coefficient on corn price in the corn quantity equation was significant and negative indicating an increase in corn price will decrease corn quantity. The corn quantity's coefficient in the cattle equation was significant and positive demonstrating a decrease in corn quantity will decrease cattle quantity. The coefficients on lagged endogenous variables were significant and positive indicating there are direct relationships between past and present quantity levels.

The coefficient on DG price in the DG quantity equation was insignificant demonstrating that the price of DG has no or little effect on the quantity of DG. Results of the cattle production model indicate there are no effects of blenders' credits (ethanol price) on corn quantity and DG

quantity. However, this result does not conclude that there are no indirect effects of blenders' credits on cattle production. The positive and significant coefficient on the RFS variable in the corn equation shows that the corn supply increased with the introduction of the RFS (mostly via increased planted corn acreage). Therefore, there is a possibility that RFS indirectly effects cattle quantity through the corn equation.

Direct effects of ethanol policy on cattle production were modeled using the reduced form of the three equation system. Cattle quantity was estimated using all predetermined variables. All variables dealing with price were insignificant in determining the cattle quantity. The coefficient on the RFS dummy variable is positive and significant demonstrating the production of cattle increased with the introduction of the RFS. The RFS increased the production of ethanol and increased the production of DG, which allowed cattle production to increase. The coefficient on the lagged corn quantity variable is positive and significant, which is logically sound since future cattle production decisions may be made from current feed availability. The coefficient on the lagged DG quantity variable is significant and negative. If there is an increase in production of DG, there is an increase in demand for corn from ethanol producers, which may decrease the availability of corn for feed. Direct effects of blender's credits (ethanol price) on cattle production are insignificant in the equation.

Results of the theoretical model indicate the possibility of ethanol policy indirectly affecting livestock production. Econometric results show a possibility of ethanol policy indirectly impacting cattle production through the RFS's influence on corn quantity. Policy makers' intentions with ethanol policy likely were to increase ethanol consumption rather than to directly affect cattle production. However, results of the reduced form equation indicate that the RFS increased the cattle quantity, which represents a direct outcome of ethanol policy on cattle

production. Policy makers can utilize the information provided in this study to understand the

effects of ethanol policy on multiple agricultural markets. Understanding the existence of

indirect and direct effects of newly designed policies on non-targeted markets adds credibility to

the policy making process.

Table 1. Results of weighted two-stage least squares estimation

Variables	Coefficient	t-Statistic	p-value
Cattle quantity equation			
CONSTANT	1.126	1.33	0.19
LOG(CORNQ)*	0.053	1.63	0.1
LOG(DGQ)	-0.015	-1.55	0.12
LOG(CATQ(-1))***	0.807	9.46	< 0
QT2	-0.002	-0.11	0.91
QT3***	0.105	3.71	< 0
QT4***	0.172	4.04	< 0
TIME	0.001	1.04	0.3
R-square = 0.894 and DW statistics 1.951			
Corn quantity equation			
CONSTANT***	6.15	8.01	< 0
LOG(CORNP)***	-0.237	-4.56	< 0
LOG(ETHP)	0.037	0.55	0.59
QT2***	-0.804	-6.63	< 0
QT3***	-1.04	-11.21	< 0
QT4***	-1.418	-23.82	< 0
TIME***	0.003	3.08	< 0
RFS*	0.111	1.92	0.06
LOG(CORNQ(-	0.4	4.23	< 0
R-square = 0.966 and DW statistics 1.925			
DG quantity equation			
CONSTANT**	1.309	2.12	0.04
LOG(DGP)	-0.046	-0.77	0.44
LOG(ETHP)	0.066	0.82	0.41
TIME*	0.003	1.88	0.06
RFS	0.015	0.23	0.82
LOG(ETHP(-2))	0.091	1.09	0.28
LOG(DGQ(-1))***	0.909	19.28	< 0
R-square = 0.989 and DW statistics 2.013			

*** Indicates significance at the 1% level
**Indicates significance at the 5% level
*Indicates significance at the 10% level

Table 2. Results of ordinary least squares estimation of Cattle quantity equation

Variables	Coefficient	t-Statistic	p-value
Cattle quantity equation			
C***	3.001	3.33	0
LOG(CORNP)	0.042	1.62	0.11
LOG(ETHP)	-0.031	-1.63	0.11
LOG(DGP)	-0.034	-1.21	0.23
QT2***	-0.09	-2.62	0.01
QT3	0.001	0.03	0.97
QT4***	0.069	4.01	0
T**	0.001	2.48	0.02
RFS**	0.034	2.16	0.04
LOG(CATQ(-1))***	0.618	6.32	0
LOG(CORNQ(-1))*	0.051	1.89	0.06
LOG(ETHP(-2))	-0.017	-0.88	0.38
LOG(DGQ(-1))*	-0.033	-2.5	0.02
R-square = 0.915 and DW statistics 2.078			

*** Indicates significance at the 1% level
**Indicates significance at the 5% level
*Indicates significance at the 10% level

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Footnotes:

[1] The results of this study will focus on cattle production. However, this study may be adapted to different livestock species.

[2] This is a note on how to interpret the vector of right hand side of variables. For example,

$$\eta_{xZ_1} EZ_1 = \frac{Z_1}{x} \frac{\delta D_1}{\delta Z_1}\bigg|_{P_x} = \frac{Z_1}{dZ_1} \frac{dD_1}{x}\bigg|_{P_x} ; \text{ but x=}D_1, \text{ so } \Rightarrow \frac{ED_1}{EZ_1} = \frac{Ex}{EZ_1}\bigg|_{P_x} ; \text{ hence } \eta_{xZ_1} EZ_1 = \frac{Ex}{EZ_1}\bigg|_{P_x}$$

$$* \ EZ_1 = Ex\bigg|_{P_x} = \%\Delta \text{ in ethanol demand, with } P_x \text{ held constant, that comes about due to the}$$

change in government policy. But if the price of ethanol (P_x) increases:

$$\eta_x EP_x = \frac{P_x}{x} \frac{\delta D_1}{\delta P_x}\bigg|_{Z_1} \quad EP_x = \left(\frac{Ex}{EP_x}\right)\bigg|_{Z_1} , \quad EP_x = \%\Delta \text{ in X due to price change, } Z_1 \text{ held constant.}$$

[3] Schwartz criterion penalizes additional coefficients more heavily than the Akaike criterion. Akaike criterion yielded slightly different results than the Schwartz criterion.