

THE EFFECTS OF ETHANOL POLICY ON CATTLE PRODUCTION

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ABSTRACT

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Corn-based ethanol production has increased dramatically in the past ten years, causing an increase in demand for corn by ethanol producers and an increase in production of ethanol by-products such as distillers' grains. The increase in ethanol production can be attributed to ethanol policy at the state and federal levels. Because of the increase in production of corn-based ethanol, cattle producers face greater competition for a major feed source, corn, and greater supply of an emerging feed source, distillers' grains. The objective of this study is to analyze and quantify the effects of ethanol policy on cattle production.

A theoretical model and an econometric model are used to fulfill the objectives of this study. The theoretical model contains an ethanol model and a general livestock model. Results of the theoretical model present the possibilities of ethanol policy affecting cattle production. The econometric model identifies the indirect and direct effects of ethanol policy on cattle production. The results of the econometric model indicate that there is a relationship between ethanol policy, specifically the Renewable Fuel Standard, and cattle production.

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INTRODUCTION

Background and Problem Statement

The recent ethanol boom has been fashioned by legislation at the state and federal levels (Collins, 2008). Federally, legislation for ethanol has been around since the Energy Tax Act of 1978 (Department of Energy, 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, a booming biofuel, on their feed sources. Research, detailed in this paper, will explain and analyze the effects ethanol policy has 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, which can be fed to livestock, and may counteract the diminishing supply of feed corn. However, these ethanol by-products have limitations and difficulties of their own (Fabiosa, 2008).

Current ethanol policy increases the demand for ethanol, which increases the demand for corn. The increase in ethanol production increases the production of its by-products. Livestock production is affected through the greater competition for corn supplies and the increased production of ethanol by-products. Both corn and ethanol by-products are feed sources for livestock.

Justification of Study

The increased production of ethanol, to which governmental policy contributes, has created new challenges for the livestock sector. 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 on all markets is important in lawmakers' decision-making process.

Description of Study

The effects of ethanol policy on livestock production will be analyzed in this study. Specifically, the study will utilize a combination of two models; the first is a one input-two output model and the second is a two input-one output model, which is developed based on research done by Bruce Gardner (1987) in his book titled "The Economics of Agricultural Policies." The one input-two output model represents ethanol production where corn is the single input producing two outputs, distillers' grains and ethanol. Distillers' grains and ethanol are produced in semi-fixed proportions. The outputs of the model are produced in semi-fixed proportions because of different plant efficiency levels. In the second model,

where there is two inputs and one output, corn and distillers' grains are used as inputs producing one output, livestock.

Corn is used as an input in both the production of ethanol and livestock. Distillers' grains are an output in the ethanol model and an input in the livestock model. Therefore, ethanol policy affects livestock production in two manners. First, corn is used as an input in both the production of ethanol and the production of livestock, which yields greater competition for livestock producers when acquiring corn. Second, the production of ethanol creates distillers' grains, which is another source of feed for livestock. Ethanol policy may harm livestock producers because of the increased competition for corn. However, ethanol policy may benefit livestock producers with the production of distillers' grains. Figure 1.1 shows the relationship between corn, ethanol, distillers' grains, and livestock.

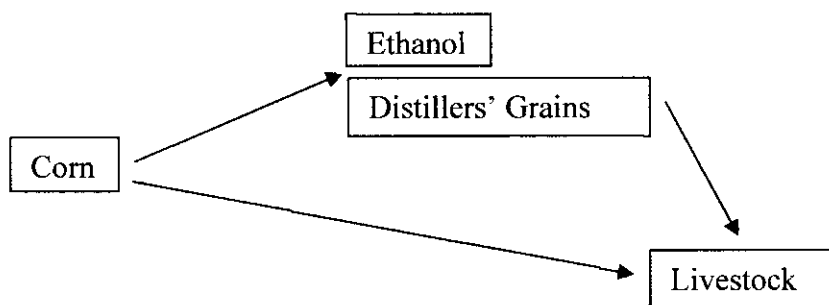


Figure 1.1. Ethanol model and livestock model.

Study Objectives

Objectives of this study are as follows:

1. Utilize a theoretical model to explain and analyze the relationship of ethanol policy and livestock production.

2. Determine the indirect effects of ethanol policy on cattle production utilizing an econometric model.¹
3. Determine the direct effects of ethanol policy on cattle production utilizing an econometric model.

Outline

Chapter 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. Chapter 3 includes a theoretical model, empirical model, and econometric model that explain the relationship between ethanol policy and livestock production. Chapter 4 consists of the results of the econometric estimation. Chapter 5 provides conclusions and implications of the research.

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

BACKGROUND INFORMATION AND LITERATURE REVIEW

Ethanol Production

The demand for ethanol in the United States predominantly comes from its use as an additive in gasoline. Ethanol can also be found in alcoholic beverages and other minor uses, but for the purpose of this study, the focus will be on fuel ethanol. The rationale for using ethanol as an additive in gasoline includes its use as an octane booster, oxygenate, and a protractor of gasoline stocks. Ethanol is generally produced and consumed in the Midwest because of the close proximity to its major feedstock, corn. Corn constitutes 95% of the feedstock used in United States production of ethanol, with the remaining 5% consisting of grain sorghum, barley, wheat, cheese whey, and potatoes. Corn is used as the primary feedstock because it is a comparatively cheap source of starch. The cornstarch can be easily converted into simple sugars, which are then fermented and distilled to produce ethanol and by-products (Yacobucci, 2008).

Ethanol is produced through either wet milling or dry milling of cereal grains. The wet milling process utilizes water and chemicals to separate the grain into different structural components. The dry milling process grinds the entire kernel into flour and processes the flour without separation of its nutritional components. The wet mill process removes the unnecessary ingredients to produce ethanol before the fermentation step, while the dry mill process does not (Renewable Fuels Association, 2008). By-products of the wet milling process include corn gluten feed and corn gluten meal. One bushel of corn converted to ethanol through the wet milling process, produces an average of 13.57 pounds of corn gluten feed and 2.58 pounds of corn gluten meal (Ferris, 2006). The production of

corn gluten feed and corn gluten meal varies between wet mill plants depending on their respective efficiency.

After the distillation step in a dry mill, the resulting products include ethanol, thin stillage, which is the remaining liquids and suspended solids, and wet distiller's grains (WDG), which is the remaining solid material. Thin stillage can be partially dehydrated to produce condensed distiller's soluble (CDS). Dried distiller's grains (DDG) are produced by dehydrating WDG. WDG, DDG, and CDS can be sold as livestock feed. CDS can also be combined with distiller's grains to form distiller's grains with solubles, which may be sold at 30% dry matter known as wet distiller's grains with solubles (WDGS), 50% dry matter known as modified distiller's grains with solubles (MDGS), or 90% dry matter known as dried distiller's grains with solubles (DDGS). All of these products can be used as feed for livestock (Tjardes and Wright, 2002). When the paper refers to distiller's grains (DG), all of the before mentioned dry mill by-products are included.

Source of Ethanol Production

Because ethanol is a substitute for gasoline in automotive fuel, ethanol demand is subject to the price of oil and its corresponding price of gasoline (Collins, 2008). Figure 2.1 contains historic gasoline prices from market year 1990 to present. Gasoline prices have risen from a low of \$0.38 per gallon in quarter two of the 1998 market year² to \$3.26 per gallon in quarter four of the 2007 market year, representing a 757% increase.

² Market year begins in September of that year. Quarter 1: September, October, and November - Quarter 2: December, January, and February - Quarter 3: March, April, and May - Quarter 4: June, July, and August.

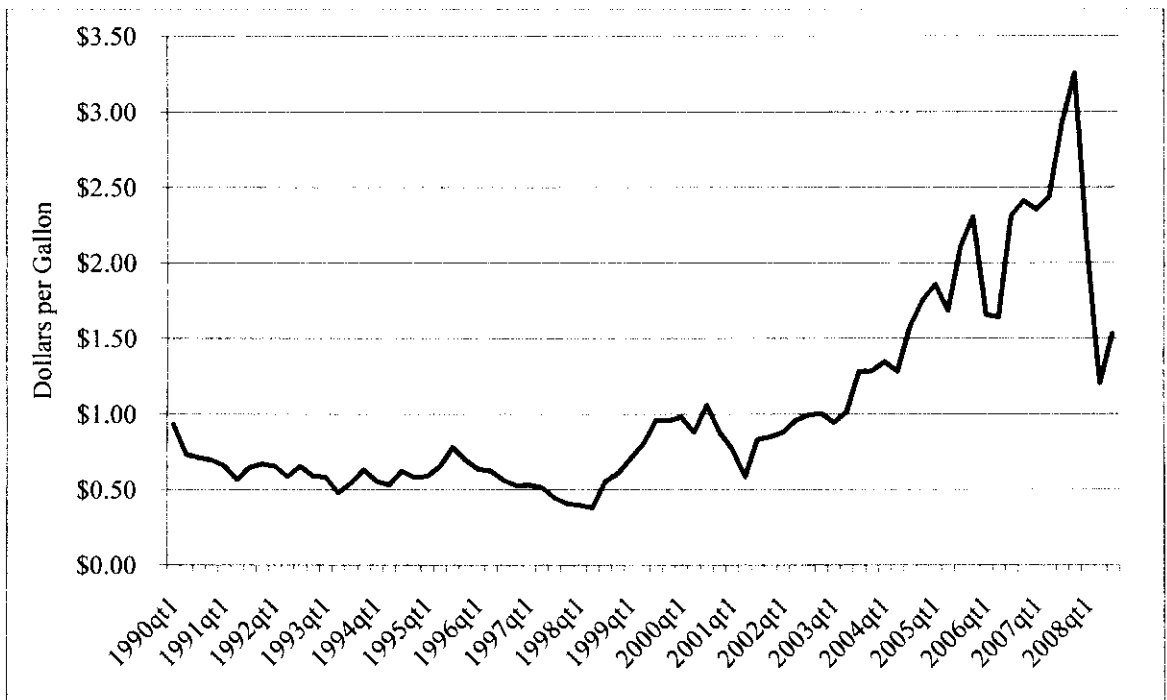


Figure 2.1. Nebraska Gasoline Price - Average \$/gallon per market year quarter.
 Source: Official Nebraska Government Website, “Ethanol and Unleaded Gasoline Average Rack Prices.” (2009).

The ethanol boom has also been fashioned by legislation at the state and federal level (Collins, 2008). Federally, legislation for ethanol has been around since the Energy Tax Act of 1978 (Department of Energy, 2008). The federal government has played an important role in expanding the ethanol industry. Compiled in Table 2.1 is federal legislation that has affected the ethanol industry in the past, present, and future. Currently, the 2008 Farm Bill has reduced the blenders’ tax credit from \$0.51 to \$0.45 per gallon while maintaining the \$0.54 per gallon import tariff and the renewable fuel standard (van der Hoeven, 2008). In order to improve the current biofuel policies, numerous studies have developed and analyzed alternative biofuel policies (e.g., Babcock, 2008a; Tyner, 2007; Tyner and Taheripour, 2007; Tyner and Taheripour, 2008).

Table 2.1. Federal legislation.

Year	Legislation
1974	The Solar Energy Research, Development, and Demonstration Act of 1974 stimulated the beginning of research in converting organic material into fuel.
1975	Lead used as an octane booster in gasoline was banned by the Environmental Protection Agency (EPA). The phasing out process began in 1975 and was completed in 1986 with the removal of all lead in gasoline. Because ethanol can be used as an octane booster, it became a more popular additive.
1978	Energy Tax Act of 1978 created a 40 cents per gallon subsidy for every gallon of ethanol blended with gasoline.
1980-84	Energy Security Act of 1980 created opportunities for new construction of ethanol plants through loans and price guarantees. Congress also implemented an import tariff on ethanol.
1983	Surface Transportation Act of 1982 increased the subsidy to 50 cents per gallon of ethanol blended into gasoline.
1984	Tax Reform Act of 1984 increased the subsidy to 60 cents per gallon of ethanol blended into gasoline.
1985	Denver, Colorado began using ethanol blended in gasoline as an oxygenate during the winter to control carbon monoxide emissions.
1988	Oxygenates blended with gasoline, such as ethanol, became popular for many areas of the country. However, Methyl Tertiary Butyl Ether (MTBE) dominated the market as the leading oxygenate used.
1990	Omnibus Budget Reconciliation Act of 1990 decreased the subsidy to 54 cents per gallon of ethanol blended into gasoline.
1992	Energy Policy Act of 1992 defined blends of at least 85% ethanol in gasoline as 'alternative transportation fuels', and required certain government car fleets to begin purchasing alternative fuel vehicles. The Clean Air Act Amendments mandated the use of oxygenated fuels in several areas of the country. However, MTBE was still the leading oxygenate used as an additive in gasoline.
1997	The major United States' auto manufacturers began producing vehicles that could run on a blend of 85% ethanol and 15% gasoline also known as E-85.
1999	MTBE began showing up in drinking water prompting some states to ban the oxygenate. Because ethanol is an alternative to MTBE, the demand for ethanol increased.
2001	The ethanol subsidy was reduced to 53 cents per gallon of ethanol blended into gasoline because of a 1998 law.
2003	The ethanol subsidy was reduced to 52 cents per gallon of ethanol blended into gasoline because of a 1998 law.
2004	American Jobs Creation Act of 2004 provided a 51 cent per gallon ethanol tax credit to oil companies that blend ethanol with gasoline. The tax credit replaced the previous per gallon ethanol subsidy and is commonly called the "blenders' credit."

Table 2.1. (Continued)

2005	Energy Policy Act of 2005 created the first Renewable Fuels Standard, which set minimums on the amount of renewable fuel consumed. The goal of the standard was to double the consumption of renewable fuel by 2012.
2007	Energy Independence Act of 2007 extended the Renewable Fuels Standard to 2022.
2008	The 2008 farm bill reduced the blenders' credit to 45 cents per gallon of ethanol blended with gasoline effective January 1, 2009.

Source: Department of Energy, "Ethanol Timeline" (2008) and American Coalition for Ethanol, "Public Policy: Federal Legislation" (2009).

There are currently two import tariffs on ethanol moving into the United States. All imports of ethanol into the United States are subject to a 2.5% ad valorem tariff, which allows the federal government to collect a 2.5% tax on the value of the ethanol imported. Second, there is a \$0.54 per gallon import tariff on ethanol, which exceeds the blender's tax credit of \$0.45. All ethanol is eligible for the blenders' credit regardless of the ethanol's country of origin. The import tariff is set higher than the blender's credit to prevent United States taxpayers' dollars from being invested into foreign countries' ethanol industry. However, the \$0.54 import tariff is exempt for Caribbean Basin Initiative (CBI) participating countries up to a quota set by the United States International Trade Commission. Ethanol must be produced in CBI participating countries to receive the exemption. In 2008, the duty free quota was set at 452 million gallons (American Coalition for Ethanol, 2009). The import tariffs promote domestic production of ethanol.

The most recent "Renewable Fuel Standard" (RFS) was specified in the Energy Independence and Security Act of 2007. The RFS contains the minimum amount of renewable fuel that must be consumed in the United States. Table 2.2 contains the most recent RFS. In the table, renewable fuel is defined as a fuel created from a renewable biomass. Renewable biomass includes crops, crop residue, trees, tree residue, animal

waste, animal by-products, algae, yard waste, and food waste. Conventional biofuel is defined as renewable fuel created from cornstarch. Advanced biofuel includes any renewable fuel, other than the ethanol produced from cornstarch (H.R.6, Energy Independence and Security Act of 2007). The RFS creates mandates on the consumption of advanced biofuel and total renewable fuel.

In Table 2.2, the conventional biofuel is calculated by subtracting advanced biofuel consumption from total renewable fuel consumption. This amount represents the maximum amount of conventional biofuel that can be used to fulfill the total renewable fuel mandate. As shown in Table 2.2, the amount of conventional biofuel continues to increase until 2015, where it remains steady at 15 billion gallons. Therefore, the RFS will continue to influence production of ethanol from corn into the future. Subsequently, the production of by-products will also continue.

Table 2.2. Renewable Fuel Standard, 2006-2022

Year	Conventional Biofuel	Advanced Biofuel -billions of gallons-	Total Renewable Fuel
2006	4.00	0.00	4.00
2007	4.70	0.00	4.70
2008	9.00	0.00	9.00
2009	10.50	0.60	11.10
2010	12.00	0.95	12.95
2011	12.60	1.35	13.95
2012	13.20	2.00	15.20
2013	13.80	2.75	16.55
2014	14.40	3.75	18.15
2015	15.00	5.50	20.50
2016	15.00	7.25	22.25
2017	15.00	9.00	24.00
2018	15.00	11.00	26.00
2019	15.00	13.00	28.00
2020	15.00	15.00	30.00
2021	15.00	18.00	33.00
2022	15.00	21.00	36.00

Source: Library of Congress, “**H.R.6**, Energy Independence and Security Act of 2007” (2007).

State legislation on renewable biofuel varies by state. State level legislation on the use of oxygenate products blended in gasoline along with state level subsidies have increased the production of ethanol. Legislation promoting the production and use of ethanol has been a major cause for the boom. Methyl tertiary butyl ether (MTBE) and ethanol have been historically blended in gasoline to produce a cleaner burning fuel in certain areas of the country.

The use of MTBE and ethanol were mandated by federal policies. In the past, MTBE was blended in gasoline more than ethanol. However, there has been a recent transition by states to use only ethanol in the blended fuel. The discovery of MTBE in ground water has caused some states to ban the use of MTBE, which increases the use of ethanol. Along with the ban on MTBE, some Midwest states such as Minnesota and North Dakota have additional ethanol policies. Minnesota, for example, has required all gasoline in the state to contain at least 10% of ethanol by volume, which will increase to 20% by 2013. North Dakota has promoted ethanol by temporarily reducing its state tax on E85 in 2005 from \$.21 to \$.01 per gallon. State support of the ethanol industry is due in large part because of the impact the production of ethanol has on farmers and rural economies. Support can also be found because of environmental concerns over pollution and relieving the U.S. dependence on foreign oil (Koo and Taylor, 2008).

Increased Ethanol Production

The increase in oil prices along with legislation on the biofuel industry has increased the production of ethanol in the United States (Collins, 2008). Ethanol production from 1990 to 2008 can be seen in Figure 2.2. As seen in the graph, ethanol

production increased annually except in 1996 when ethanol production declined 300 million gallons or 21.4%. The decline in production was a result of a tight corn supply caused by a drought in the Midwest. From 1990 to 1999, ethanol production steadily rose, increasing by 570 million gallons or 63.3% during that time. The period from 2000 to 2008 experienced an increase in ethanol production of 7,370 million gallons, which is an increase of 452%.

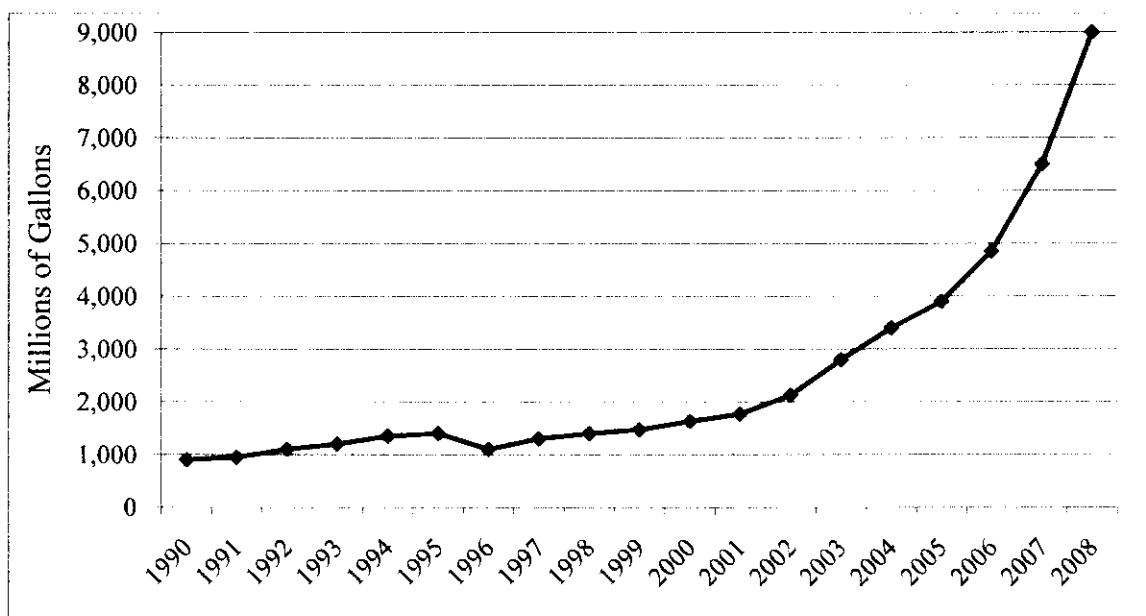


Figure 2.2. Millions of gallons of ethanol production per year.
 Source: Renewable Fuels Association, “The Industry: Statistics” (2009).

Corn Utilized in Ethanol Production

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. In Figure 2.3, the demand for corn by ethanol plants is presented. 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, in Figure 2.3, 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.

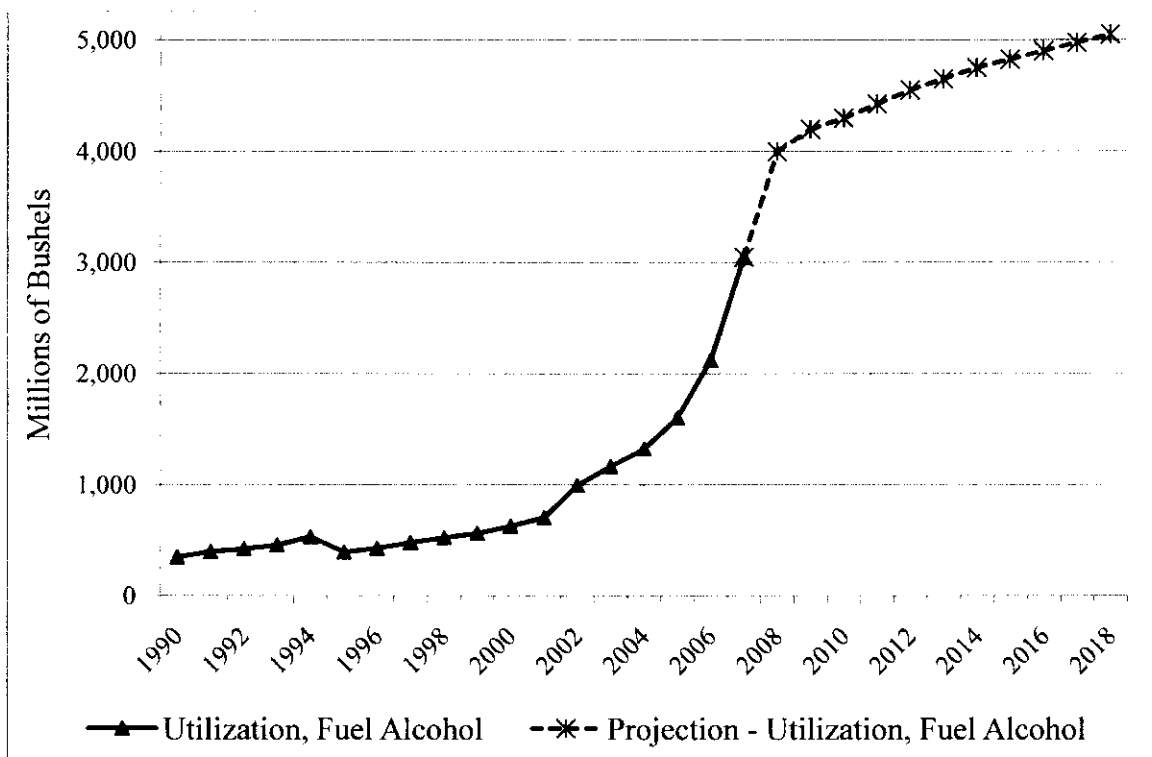


Figure 2.3. Utilization of corn for fuel alcohol per market year.
 Source: Economic Research Service, “Feed Grains Database” (2009) and Economic Research Service, “Agricultural Baseline Database” (2009). Data from market year 2008 to market year 2018 are estimates.

Corn Prices

Corn prices have recently increased to mirror the increase in demand for corn by ethanol plants. The increase in corn prices may also be attributed to six other factors. These factors include: (1) an increase in demand for all United States commodities because of the strong economic growth seen around the world; (2) declining value of the U.S. dollar relative to other currencies, which increases the demand for exports of U.S. commodities; (3) reduction of wheat and rice stocks because of unforeseen weather events causing greater demand for substitutes such as corn; (4) increased production costs for farmers, food processors, and distributors because of the high energy prices; (5) increased U.S. exports of commodities because of foreign countries' reduction of import tariffs and increased restrictions on exports of commodities; and (6) greater investment by hedge funds in agriculture commodities (Collins, 2008).

Figure 2.4 contains the Chicago Board of Trade (CBOT) average corn price per quarter between market years 1990 and 2008. CBOT corn price has risen considerably from a \$1.89 per bushel in quarter one of market year 2005 to \$6.08 per bushel in quarter four of market year 2007. The most recent corn price (quarter three of market year 2008) is \$3.97 per bushel. With the exception of market years 1995, 1996, and 2005 to 2009, corn prices have usually stayed between \$2.00 per bushel and \$3.00 per bushel since market year 1990. Corn prices jumped in market years 1995 and 1996 because of a drought in the Midwest, increased demand for United States' feed grains, and greater speculation in the corn market (Light and Shevlin, 1998).

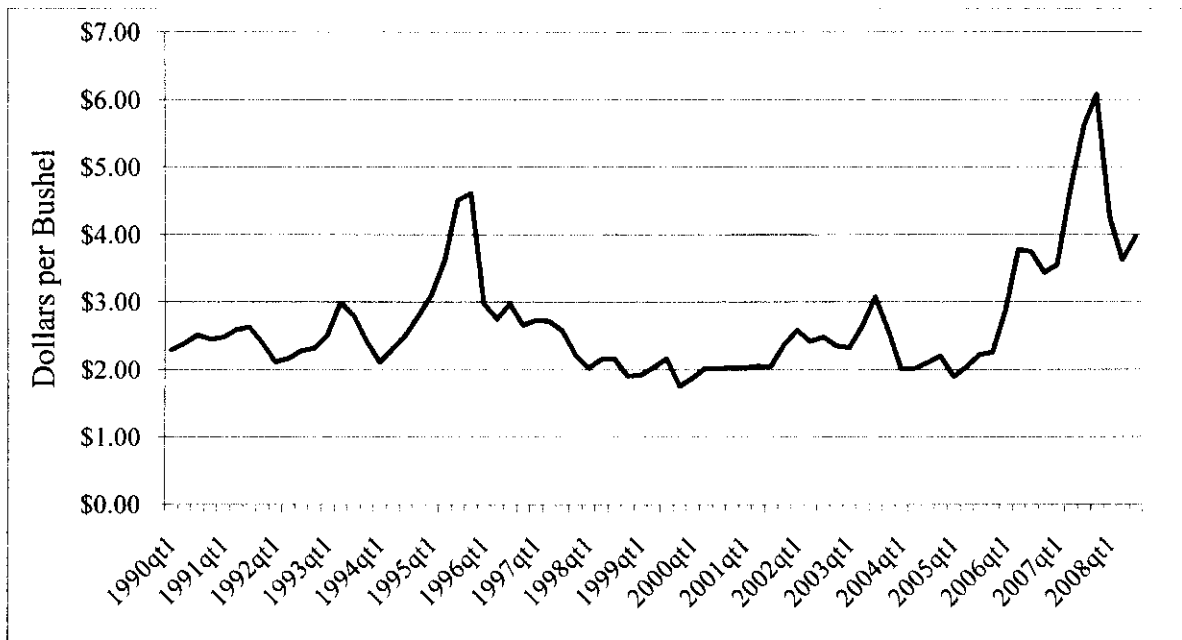


Figure 2.4. Chicago Board of Trade average corn price per market year quarter. Source: Economic Research Service, “Feed Grains Database” (2009).

By-Products and Feed

Dry mill ethanol plants have a lower start up cost when compared to wet mill plants. Therefore, the increase in demand for ethanol has caused an increase in the production of dry mills because of the lower start up cost (Ferris, 2006). In the 2000 market year, dry mills consumed 45.2% of the total corn used in both types of mills. This number jumped to 83.7% in the 2007 market year. Production of by-products from wet mill plants has remained relatively stable. However, production of DG from dry mill plants has increased with the increase in ethanol production. Since dry mill ethanol plants produce DG and ethanol from corn, the volume of DG produced is directly related to the volume of ethanol produced. From one bushel, 56 pounds of corn, approximately 17 pounds of DGs are produced along with 2.8 gallons of ethanol (Tokgoz *et al.*, 2007). The production of DG and ethanol varies from plant to plant because of differences in

efficiency. Production of DG has expanded rapidly, mirroring the growth of the ethanol industry.

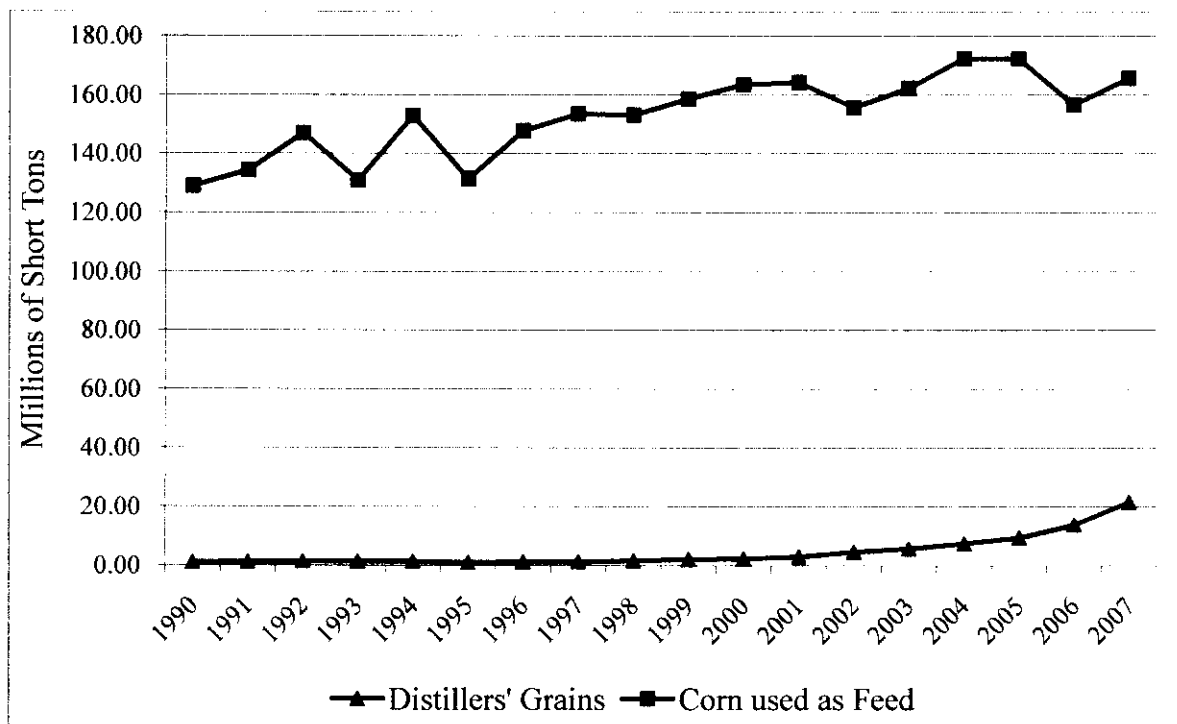


Figure 2.5. Production of distillers' grains and utilization of corn for feed per market year. Source: Economic Research Service, "Feed Grains Database" (2009), Renewable Fuels Association (2009)³, and Tokgoz *et al.*, (2007).

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, which is another source of feed for livestock. As seen in Figure 2.5, 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%. Figure 2.5 contains the yearly amount of corn used for livestock feed, which has generally increased throughout the period. However, the

³ Data on production levels of dry and wet mill ethanol plants was obtained via email from the Renewable Fuels Association.

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, DG 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). A similar article created a model to find the economically optimum inclusion rate of DG in finishing beef cattle rations subject to different factors. The model incorporated nutritional guidelines, feed costs, transportation costs, and manure disposal costs. 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. Inclusion rates of 40% to 50% in beef cattle feed rations are appropriate (Loy, 2006).

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. If DG costs are low enough, they can be used as a substitute energy source in pork or poultry feed rations (Stillman, Haley, and Mathews, 2009). The maximum inclusion rate of DG for dairy is 20-25%, for growing and finishing hogs is 20%, and for growing and finishing poultry is 15% (Westcott, 2007; Renewable Fuels Association, 2008). 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.

Nutritional factors play a role in deciding the inclusion rate of DG in livestock feed rations (Clemens and Babcock, 2008; Tjardes and Wright, 2002). High levels of sulfur in ruminant animal's feed and water can lead to polioencephalomalacia (PEM), which may be fatal. Sulfur from corn is concentrated during the production of ethanol and leads to a greater sulfur content in DG. In addition, sulfuric acid is used to control the pH level in a dry mill plant, which creates higher sulfur content in DG. Sulfur content is one of the leading constraints in the maximum inclusion level of DG in finishing beef cattle diets.

Another leading constraint is fat content. Fat content of 6% or greater in beef and dairy cattle feed ration can lead to depressed fiber digestion and intake. DDG can contain up to 13% fat and CDS can contain up to 15% fat (Clemens and Babcock, 2008; Tjardes and Wright, 2002).

By-products of ethanol production contain high amounts of phosphorus, which is beneficial when additional phosphorus is needed in livestock diets. However, surplus phosphorus can lead to difficulties in disposal of manure because of phosphorus run-off problems and extra costs associated with spreading manure on greater acreage (Schingoethe, 2007). These challenges and constraints must be understood to include DG in livestock feed rations.

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 not only determined by availability but, also by price. Figure 2.6 shows the price of DG relative to the price of corn using the same units of measure. Therefore when the ratio is greater than one or 100%, the price of DG is greater than the price of corn and vice versa. The two prices are equal at 100%, which is represented by the thick line on Figure 2.6. 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. 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. Livestock feed availability and price are important factors in feed

ration decisions. Finally, another way to compare different feed sources is through their value based off their respectful protein and energy content (Ferris, 2006).

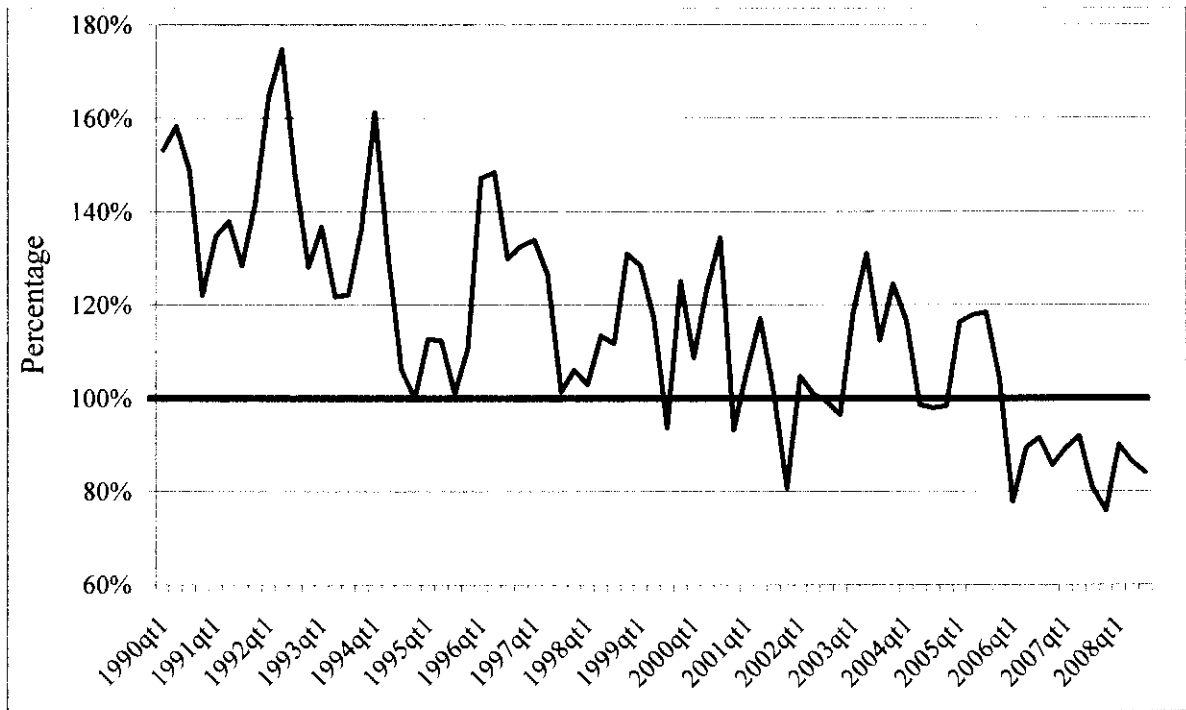


Figure 2.6. Ratio of DG price to corn price per market year quarter.
 Source: Economic Research Service “Feed Grains Database” (2009).

Cattle Production

Ruminant animals have the best ability to digest DG (Mathews Jr. and McConnell, 2009). Beef cattle are ruminants. Beef cattle have higher maximum amount of DG inclusion rates in feed rations, compared to other livestock. Therefore, the results of this study will focus on determining the effects of ethanol policy on beef cattle production. Figure 2.7 contains the pounds of beef slaughtered under federal inspection. The quantity of beef slaughtered per market year has increased in general over the period of market year 1990 to market year 2007. However, the year-to-year quantity of beef slaughtered decreased four times during that period with the largest decrease between the market years

2002 and 2003 at a decline of 8.61%. Livestock production may be influenced by the competition for corn, the price of corn, the supply of DG, the price of DG, the price of energy, and the price of the livestock.

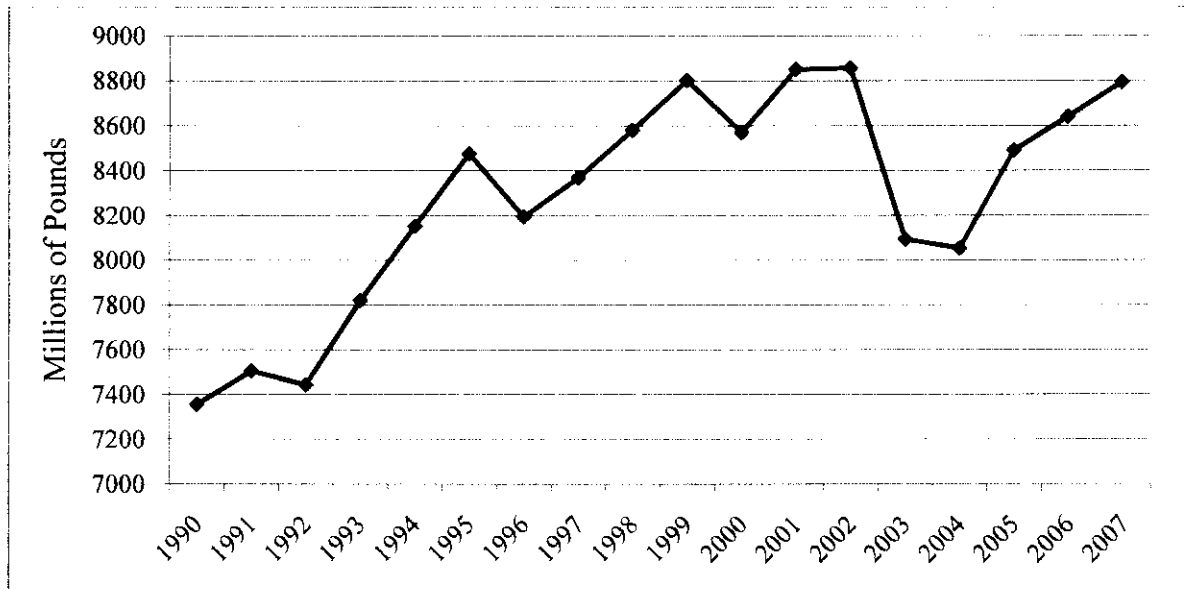


Figure 2.7. Federal inspection of beef in millions of pounds per market year. Source: Livestock Marketing Service Center, "Members Only" (2009).

Supporters and Opponents of Ethanol

Supporters of ethanol argue it decreases the dependency on foreign oil and it decreases emissions produced by gasoline internal engines. Opponents of ethanol argue that the production of ethanol increases food prices because it increases the demand for corn. They also argue the production of ethanol uses more energy and emits more pollutants compared to the production of gasoline (Schnepf, 2007).

The increased production of ethanol can be attributed to the increase in gasoline prices and policies set by federal and state legislation. The increase in the production of ethanol has increased the production of distiller's grains and increased the demand for corn,

which has attributed to the increase in corn prices.⁴ Livestock producers are faced with greater competition for corn and an increased supply of an emerging feed source, distillers' grains.

Welfare Effects

Studies dealing with the effects of ethanol policy on producer and consumer welfare suggest the overall total welfare effect is negative (Du, Hayes, and Baker, 2008). The study presented the 2007 welfare effects of the \$0.51 blenders' credit on the corn, gasoline, and ethanol markets along with the United States economy. Their results indicate the welfare change in the corn market was a positive 1.33 billion dollars, which was greater than the gasoline market at .29 billion dollars. Because of the blenders' credit paid by taxpayers, the change in welfare was a loss of 2.4 billion dollars in the ethanol market. Total change in welfare in 2007 equaled a loss of .79 billion dollars for the U.S. economy (Du, Hayes, and Baker, 2008).

The study conducted by Babcock (2008b) concluded that U.S. ethanol policy creates a massive net welfare loss to the economy and the policy causes the transfer of welfare from taxpayers and non-ethanol corn users, such as livestock producers, to corn growers, fuel blenders, and ethanol producers. The study investigated the change in welfare due to different U.S. ethanol policies and gasoline prices. Results for the scenario with \$2.00 per gallon of gasoline show a removal of the \$0.51 blenders' credit while keeping the 7.5 billion gallons of ethanol mandate yields a net welfare gain of 3,137 million dollars. The other policy option was an expansion of the Renewable Fuels

⁴ In addition, the increase in demand for corn has created a technology change in the corn industry. This technology change has increased corn yields.

Standard to 15 billion gallons with a modified blenders' credit, which yielded results of a loss of 269 million dollars in net welfare when gasoline is \$2.00 per gallon. The study also indicates that the existence of the ethanol industry creates a corn price floor (Babcock, 2008b).

From the corn producers' prospective, the biofuel policies can act as a substitute to other agriculture policies that are intended to increase their welfare. The biofuel policy decreases deficiency payments paid to farmers and increases producer surplus (Hochman, Sexton, and Zilberman, 2008). However under the assumption that a deficiency payment program costs taxpayers the same as an ethanol subsidy program, corn growers and domestic consumers of corn would be better off (Gardner, 2003). Under the same assumption, net welfare loss is greater for an ethanol policy program compared to a deficiency payment program in both the short and long run (Gardner, 2007).

Studies have also compared the net welfare effects of the U.S. ethanol policy with respect to the domestic and global economies (Schmitz, Moss, and Schmitz, 2007). The study indicates that the domestic net welfare gains were 2,274 million dollars when the elasticity of supply of corn was 0.5 and 3,388 million dollars when the elasticity of supply of corn was 0.7. Global net welfare gains were 1,281 million dollars and 2,594 million dollars when the elasticity of supply of corn was 0.5 and 0.7, respectively. The study specifies the net welfare gains would be net welfare costs if the consumer surplus on the gasoline market were removed from the analysis. With respect to the cattle market, the study concluded that ethanol policy would create a welfare loss. However, the study did not include DG in the analysis (Schmitz, Moss, and Schmitz, 2007).

Biofuel Policy Effects on Agriculture

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. Table 2.3 summarizes the multiple studies that have used this method in some similar fashion.

Table 2.3. Literature findings.

Study	Baseline and Scenarios; Scenarios are compared to the baseline.	Results % change from baseline
(Tokgoz, 2009)	<ul style="list-style-type: none"> ▪ <i>Forecast:</i> 2008-2017; European Union; ▪ <i>Scenario 1:</i> 10-Euro per barrel increase in oil prices; ▪ <i>Scenario 2:</i> 10-Euro per barrel increase in oil prices with removal of ethanol import tariff. 	<ul style="list-style-type: none"> ▪ <i>Year:</i> Average 2008-2017; ▪ <i>Scenario 1:</i> 1.54% ethanol production, 1.54% DG production, 0.1% corn price, -5.35% DG price; ▪ <i>Scenario 2:</i> -1.62% ethanol production, -1.62% DG production, -0.11% corn price, and 5.78% DG price.
(Peters <i>et al.</i> , 2009)	<ul style="list-style-type: none"> ▪ <i>Forecast:</i> 2006-2017; ▪ <i>Scenario 1:</i> 20% increase in demand for ethanol. 	<ul style="list-style-type: none"> ▪ <i>Year:</i> 2017; ▪ <i>Scenario 1:</i> 0.8% corn production, -1.1% beef production.
(Economic Research Service and Office of the Chief Economist, 2007)	<ul style="list-style-type: none"> ▪ <i>Forecast:</i> 2007-2016; ▪ <i>Baseline:</i> 12 billion gallons of ethanol produced per year in 2016; ▪ <i>Scenario 1:</i> 15 billion gallons of ethanol produced per year in 2016; ▪ <i>Scenario 2:</i> 20 billion gallons of ethanol produced per year in 2016. 	<ul style="list-style-type: none"> ▪ <i>Year:</i> Average 2007-2016; ▪ <i>Scenario 1:</i> 6.3% corn price, -5.9% corn used as feed, 0.1% beef production, and 0.5% fed steer price; ▪ <i>Scenario 2:</i> 15.7% corn price, -13% corn used as feed, .6% beef production, and 1.5% fed steer price.
(Tokgoz <i>et al.</i> , 2008)	<ul style="list-style-type: none"> ▪ <i>Forecast:</i> 2008-2016; ▪ <i>Scenario 1:</i> \$10 per barrel increase in oil prices; ▪ <i>Scenario 2:</i> Drought in 2012 utilizing crop yield patterns from the 1988 drought. 	<ul style="list-style-type: none"> ▪ <i>Year:</i> 2016 for scenario 1, 2012 and 2013 for scenario 2 (2013 was used for beef price and production, 2012 all other variables); ▪ <i>Scenario 1:</i> 20% corn price, -12% corn used as feed, 16.5% DG price, 67.8% DG production, 2.1% beef price, and -1.5% beef production; ▪ <i>Scenario 2:</i> 43.8% corn price, -16% corn used as feed, 40.4% DG price, -0.3% DG production, 3.9% beef price, and -2.5% beef production.

Table 2.3. (Continued)

(McPhail and Babcock, 2008)	<ul style="list-style-type: none"> ▪ <i>Forecast</i>: September 1, 2008 to August 31, 2009; ▪ <i>Scenario 1</i>: Removal of RFS mandate; ▪ <i>Scenario 2</i>: Removal of blenders' credit; ▪ <i>Scenario 3</i>: Removal of import tariff on ethanol; ▪ <i>Scenario 4</i>: Removal of all ethanol programs. 	<ul style="list-style-type: none"> ▪ <i>Year</i>: 2008 crop year; ▪ <i>Scenario 1</i>: 1.1% corn feed demand and -3.9% corn price; ▪ <i>Scenario 2</i>: 0.9% corn feed demand and -3.5% corn price; ▪ <i>Scenario 3</i>: 0.7% corn feed demand and -2.5% corn price; ▪ <i>Scenario 4</i>: 3.9% corn feed demand and -14.5% corn price.
(Hayes <i>et al.</i> , 2009)	<ul style="list-style-type: none"> ▪ <i>Forecast</i>: 2006-2022; ▪ <i>Scenario 1</i>: 40% increase in crude oil prices and 19% increase in natural gas prices; ▪ <i>Scenario 2</i>: Scenario 1 with removal of tax credits; ▪ <i>Scenario 3</i>: Removal of all biofuel programs. 	<ul style="list-style-type: none"> ▪ <i>Year</i>: Average 2006-2022; ▪ <i>Scenario 1</i>: 19.56% corn price, 3.16% beef price, and 3.14% beef production; ▪ <i>Scenario 2</i>: 0.65% corn price, -0.09% beef price, and 0.39% beef production; ▪ <i>Scenario 3</i>: -18.39% corn price, -2.86% beef price, and -1.62% beef production.
(Kruse <i>et al.</i> , 2007)	<ul style="list-style-type: none"> ▪ <i>Forecast</i>: 2011-2016; ▪ <i>Baseline</i>: continuation of blenders' credits and import tariff; ▪ <i>Scenario 1</i>: Removal of import tariff on January 1, 2009 and removal of ethanol blenders' credits on January 1, 2011. 	<ul style="list-style-type: none"> ▪ <i>Year</i>: Average 2011-2016; ▪ <i>Scenario 1</i>: 6.8% corn used as feed, -9.6% corn price, 10.7% DG price, 0.2% beef production, and -0.6% fed steer price.
(Tokgoz <i>et al.</i> , 2007)	<ul style="list-style-type: none"> ▪ <i>Forecast</i>: 2007-2016; ▪ <i>Scenario 1</i>: \$10 per barrel increase in oil prices with no E-85 Bottleneck. 	<ul style="list-style-type: none"> ▪ <i>Long-run equilibrium</i>; ▪ <i>Scenario 1</i>: 22.26% corn production, -14.68% corn used as feed, 40.32% corn price, 122.09% DG production, 36.31% DG price, -1.68% cattle slaughtered, 8.61% fed steer price.

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, Elobeid, and Faisoa *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).

MATERIALS AND METHODS

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. 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. The combination of the two models creates the theoretical framework for this study, which was adopted from work done by Gardner (1987). Other sources include Bruce Gardner's work on the spread between farm and retail prices along with work on the effects of commodity policies on land values (Gardner, 1975; Gardner, 2002).

Ethanol Model

Corn is the input of the ethanol model producing ethanol and DG. Figure 3.1 represents the ethanol model.

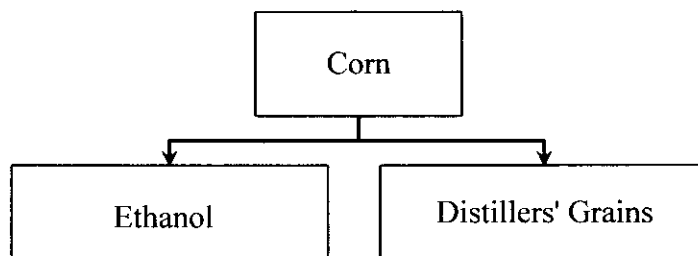


Figure 3.1. Ethanol model.

The ethanol model's notation is as follows:

$x = \text{Demand for ethanol}$

P_x = Price of ethanol (dollars/unit of ethanol)

Z_1 = Shift variable (e.g., some government policy affecting ethanol)

y = Demand for DG

P_y = price of DG (dollars/unit of DG)

Z_2 = Shift variable (e.g., some government policy affecting DG)

a = Supply of corn

P_a = Price of corn (dollars/unit of corn)

Z_3 = Shift variable (e.g., some government policy variable affecting corn)

P_s = Processing service (dollars/unit of corn)

$$\gamma_x = \frac{\text{tons of grain}}{\text{tons of ethanol}} = \frac{a}{x}$$

$$\gamma_y = \frac{\text{tons of grain}}{\text{tons of DG}} = \frac{a}{y}$$

The ethanol model begins with six equations:

$$(1) \quad x = D_1(P_x, Z_1)$$

$$(2) \quad y = D_2(P_y, Z_2)$$

$$(3) \quad a = g(P_a, Z_3)$$

$$(4) \quad a = \gamma_x * x \quad \text{Production relation of corn and ethanol.}$$

$$(5) \quad a = \gamma_y * y \quad \text{Production relation of corn and DG.}$$

$$(6) \quad P_a = \left(\frac{1}{\gamma_x}\right) * P_x + \left(\frac{1}{\gamma_y}\right) * P_y - P_s$$

Where:

$$\left(\frac{1}{\gamma_x}\right) = \frac{\text{tons of ethanol}}{1 \text{ ton of corn}}$$

$$\left(\frac{1}{\gamma_y}\right) = \frac{\text{tons of DG}}{1 \text{ ton of corn}}$$

To examine the effects of an exogenous change, the six equations are totally differentiated.

$$(7) \quad dx = \frac{\delta x}{\delta P_x} dP_x + \frac{\delta x}{\delta Z_1} dZ_1$$

$$(8) \quad dy = \frac{\delta y}{\delta P_y} dP_y + \frac{\delta y}{\delta Z_2} dZ_2$$

$$(9) \quad da = \frac{\delta a}{\delta P_a} dP_a + \frac{\delta a}{\delta Z_3} dZ_3$$

$$(10) \quad da = \gamma_x dx$$

$$(11) \quad da = \gamma_y dy$$

$$(12) \quad dP_a = \frac{1}{\gamma_x} dP_x + \frac{1}{\gamma_y} dP_y$$

The changes are then expressed in terms of change, for which elasticity notation will be

used. Also, note that E_x means $\frac{dx}{x}$ or percentage change. The elasticity relationships are:

$$(13) \quad \frac{dx}{x} = \left(\frac{P_x}{x} \frac{\delta D_1}{\delta P_x}\right) * \frac{dP_x}{P_x} + \left(\frac{Z_1}{x} \frac{\delta D_1}{\delta Z_1}\right) * \frac{dZ_1}{Z_1}$$

Where:

$$\frac{dx}{x} = Ex^d \quad \left(\frac{P_x}{x} \frac{\delta D_1}{\delta P_x}\right) = \eta_x \quad \frac{dP_x}{P_x} = EP_x \quad \left(\frac{Z_1}{x} \frac{\delta D_1}{\delta Z_1}\right) = \eta_{xZ_1} \quad \frac{dZ_1}{Z_1} = EZ_1$$

$$(14) \quad Ey^d = \eta_y EP_y + \eta_{yZ_2} EZ_2$$

$$(15) \quad Ea^s = e_a EP_a + e_{aZ_3} EZ_3$$

$$(16) \quad Ea = Ex$$

$$(17) \quad Ea = Ey$$

$$(18) \quad EP_a = K_x EP_x + K_y EP_y$$

Note: (18) is derived from (12):

$$dP_a = \frac{1}{\frac{a}{x}} dP_x + \frac{1}{\frac{a}{y}} dP_y$$

$$\frac{dP_a}{P_a} = \frac{x}{a} \frac{P_x}{P_a} \frac{dP_x}{P_x} + K_y EP_y$$

$$\text{Where: } \frac{x}{a} \frac{P_x}{P_a} = K_x \text{ and } \frac{dP_x}{P_x} = EP_x$$

Note: 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.

In matrix form:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & -\eta_x & 0 \\ 0 & 0 & 1 & 0 & 0 & -\eta_y \\ 1 & 0 & 0 & -e_a & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -K_x & -K_y \end{bmatrix} * \begin{bmatrix} Ea \\ Ex \\ Ey \\ EP_a \\ EP_x \\ EP_y \end{bmatrix} = \begin{bmatrix} \eta_{xz_1} EZ_1 \\ \eta_{yz_2} EZ_2 \\ e_{az_3} EZ_3 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Now, 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 $EZ_1 > 0 \Rightarrow$ demand for ethanol shifts to the right.

Note: How to interpret $\eta_{xz_1} EZ_1 = \frac{Z_1}{x} \frac{\delta D_1}{\delta Z_1} \Big|_{P_x}$

$$= \frac{Z_1}{dZ_1} \frac{dD_1}{x} \Big|_{P_x}; \text{ but } x=D_1, \text{ so } \Rightarrow \frac{ED_1}{EZ_1} = \frac{Ex}{EZ_1} \Big|_{P_x}$$

So $\eta_{xz_1} EZ_1 = \frac{Ex}{EZ_1} \Big|_{P_x} * EZ_1 = Ex \Big|_{P_x} = \% \Delta \text{ in ethanol demand with } P_x \text{ held constant, that}$

comes about due to the change in government policy.

But if the price of ethanol (P_x) increases:

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

constant.

$$\begin{bmatrix} 1 & -\eta_x & 0 \\ 1 & 0 & -\eta_y \\ 1 & 0 & -e_a K_y \end{bmatrix} * \begin{bmatrix} \frac{EP_a}{EZ_1} \\ \frac{EP_x}{EZ_1} \\ \frac{EP_y}{EZ_1} \end{bmatrix} = \begin{bmatrix} \eta_{xz_1} \\ 0 \\ 0 \end{bmatrix} \quad \text{Assuming } EZ_2 = 0 \text{ and } EZ_3 = 0$$

By Cramer's Rule:

$$(19) \quad \frac{EP_x}{EZ_1} = \frac{\overset{(+)}{-} \eta_{xz_1} \overset{(-)}{\eta_y} + \overset{(+)}{\eta_{xz_1}} \overset{(+)}{e_a} \overset{(+)}{K_y}}{\underset{(+)}{D}} > 0 \quad \text{Price of ethanol must increase.}$$

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

$$(20) \quad \frac{EP_y}{EZ_1} = \frac{\overset{(+)}{-} \eta_{xz_1} \overset{(+)}{e_a} \overset{(+)}{K_x}}{\underset{(+)}{D}} < 0 \quad \text{Price of DG must fall.}$$

From eq. (18),

$$(21) \quad \frac{EP_a}{EZ_1} = K_x * \frac{EP_x}{EZ_1} + K_y * \frac{EP_y}{EZ_1} = \frac{K_x [-\eta_{xz_1} \eta_y + \eta_{xz_1} e_a K_y] - K_y \eta_{xz_1} * e_a K_x}{D}$$

$$(22) \quad \frac{EP_a}{EZ_1} = \frac{-K_x \overset{(+)}{\eta_{xz_1}} \overset{(+)}{\eta_y}}{\overset{(+)}{D}} > 0 \quad \text{Price of corn must increase.}$$

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.

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. From the ethanol model, the price of corn increases and the DG price decreases as a result of the ethanol policy. The livestock model is represented by Figure 3.2.

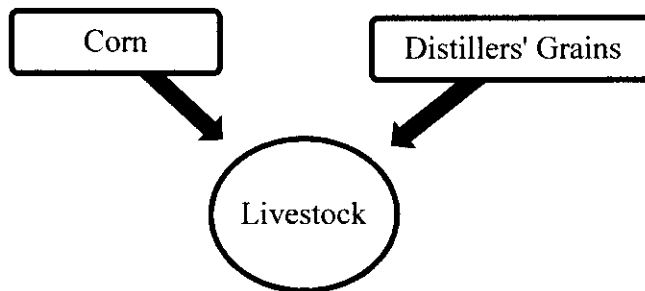


Figure 3.2. Livestock model.

First, six equations represent the livestock model.

$$(23) \quad \text{Livestock Industry Production: } x^s = f(a^d, b^d)$$

a^d = quantity of corn demanded and

b^d = quantity of DG demanded

Equation (24) and (25) come from the first order condition (FOC) of profit maximization.

(24) Demand for corn: $P_a = P_x * f_a(a^d, b^d)$

f_a = Partial derivative with respect to 'a' (corn)

P_x = Price of livestock

P_a = Price of corn

(25) Demand for DG: $P_b = P_x * f_b(a^d, b^d)$

f_b = Partial derivative with respect to 'b' (DG)

P_x = Price of livestock

P_b = Price of DG

(26) Supply of Corn: $a^s = g(P_a - T_a)$

(27) Supply of DG: $b^s = h(P_b - T_b)$

(28) Demand for Livestock: $x^d = D(P_x)$

Assumptions of the model:

- 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 an indirect subsidy. From the Joint Products Model that ethanol subsidy causes corn prices to increase and DG prices to decrease so:

$$T_a = \frac{\delta P_a}{\delta Z_1} \Rightarrow \text{Indirect subsidy for corn}$$

$$T_b = \frac{\delta P_b}{\delta Z_1} \Rightarrow \text{Indirect Tax for DG}$$

Equations (23) – (28) are totally differentiated around $T_a = 0$ and $T_b = 0$.

$$(29) \quad Ex^s - k_a E_a - k_b E_b = 0$$

$$(30) \quad -EP_x + \frac{k_b}{\varphi} E_a - \frac{k_b}{\varphi} E_b + EP_a = 0$$

$$(31) \quad -EP_x - \frac{k_a}{\varphi} E_a + \frac{k_a}{\varphi} E_b + EP_b = 0$$

$$(32) \quad \frac{1}{e_a} E_a - EP_a = ET_a$$

$$(33) \quad \frac{-1}{e_b} E_b + EP_b = ET_b$$

$$(34) \quad Ex - \eta EP_x = 0$$

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 matrix is presented 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 .

$$(35) \quad \frac{EP_x}{ET_a} = \frac{\overset{(+)(+)(+)(+)}{k_a e_a (e_b + \varphi)}}{\underset{(+)}{D}} > 0$$

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

$$(36) \quad \frac{Ex}{ET_a} = \frac{\overset{(+)(-)(+)(+)(+)}{k_a \eta e_a (e_b + \varphi)}}{\underset{(+)}{D}} < 0$$

$$(37) \quad \frac{EP_a}{ET_a} = \frac{\overset{(+)(+)(+)(+)(+)(-)}{e_a (e_b + k_a \varphi - k_b \eta)}}{\underset{(+)}{D}} > 0$$

$$(38) \quad \frac{Ea}{ET_a} = \frac{\overset{(+)(+)(-)}{e_a \varphi \eta} - \overset{(+)(+)(+)}{e_b (k_b \varphi - k_a \eta)}}{\underset{(+)}{D}} < 0$$

Dividing equation (36) by equation (37) calculates the effects of a change in price of corn on the production of livestock, which is represented by Ex/EP_a in equation (35). In addition, dividing equation (36) by equation (38) calculates the effects of a change in the quantity of corn on the production of livestock, which is represented by Ex/Ea in equation (40).

$$(39) \quad \frac{Ex}{EP_a} = \frac{k_a \eta (e_b + \varphi)}{e_b + k_a - k_b \eta} < 0$$

$$(40) \quad \frac{Ex}{Ea} = \frac{k_a \eta e_a (e_b + \varphi)}{e_a \varphi \eta - e_b (k_b \varphi - k_a \eta)} > 0$$

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

$$(41) \quad \frac{EP_x}{ET_b} = \frac{k_b e_b (e_a + \varphi)}{D} > 0$$

$$(42) \quad \frac{Ex}{ET_b} = \frac{k_b \eta e_b (e_a + \varphi)}{D} < 0$$

$$(43) \quad \frac{EP_b}{ET_b} = \frac{e_b (e_a + k_b \varphi - k_a \eta)}{D} > 0$$

$$(44) \quad \frac{Eb}{ET_b} = \frac{e_b \varphi \eta - e_a (k_a \varphi - k_b \eta)}{D} < 0$$

Dividing equation (42) by equation (43) calculates the effects of a change in price of DG on the production of livestock, which is represented by Ex/EP_b in equation (45). In addition, dividing equation (42) by equation (44) calculates the effects of a change in the quantity of DG on the production of livestock, which is represented by Ex/Eb in equation (46).

$$(45) \quad \frac{Ex}{EP_b} = \frac{k_b \eta (e_a + \varphi)}{e_a + k_b - k_a \eta} < 0$$

$$(46) \quad \frac{Ex}{Eb} = \frac{k_b \eta e_b (e_a + \varphi)}{e_b \varphi \eta - e_a (k_a \varphi - k_b \eta)} > 0$$

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.

Empirical Model

From the general theoretical model consisting of an ethanol model and a livestock model, the empirical model emphasizes on a cattle model. A cattle model was developed to evaluate the effects of ethanol policy on the production of cattle using two inputs, corn and DG. The data used in the estimation are reported quarterly with a proportion of the data collected monthly and aggregated into quarterly data. The time period of the data was maximized given variable constraints at 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, Variables, and Data

t	Subscript used to indicate time period
i	Subscript used to indicate the independent variable number
β_i	Coefficient used to represent the i^{th} independent variable
$\text{corn}q_t$	Corn quantity in time period t
$\text{dg}q_t$	Distillers' grains quantity in time period t
$\text{cat}q_t$	Cattle quantity in time period t
$\text{corn}p_t$	Corn price in time period t
$\text{eth}p_t$	Ethanol price in time period t
$\text{dg}p_t$	Distillers' grains price in time period t
rfs_t	Dummy variable representing the Renewable Fuels Standard in time period t
$\text{qt}2_t$	Dummy variable representing quarter two in time period t
$\text{qt}3_t$	Dummy variable representing quarter three in time period t
$\text{qt}4_t$	Dummy variable representing quarter four in time period t
time_t	Arbitrary variable representing the time period for time period t
$\log(\rho)$	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.

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/FeedGrainsQueryable.aspx>)

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/FeedGrainsQueryable.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/FeedGrainsQueryable.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.

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. The empirical cattle quantity equation is as follows:

$$(47) \quad catq_t = f(cornq_t, dgq_t)$$

where the quantity of cattle produced ($catq_t$) is a function of corn quantity ($cornq_t$) and DG quantity (dgq_t). Under the assumption of equilibrium where demand equals supply, the corn quantity and DG quantity equations are formulated. First, the empirical corn demand equation is presented.

$$(48) \quad cornq_t = f(cornp_t, ethp_t, rfs_t)$$

where the quantity of corn ($cornq_t$) supplied is a function of corn price ($cornp_t$), ethanol price ($ethp_t$), and a dummy variable representing the Renewable Fuel Standard adopted in 2005 (rfs_t). Both the ethanol price variable and the RFS dummy variable represent ethanol policy. The ethanol price variable factors in the blenders' credit and the RFS dummy variable represents the ethanol consumption mandate introduced in 2005. The empirical demand equation for DG is quite similar to the corn demand equation and is presented below.

$$(49) \quad dgq_t = f(dgp_t, ethp_t, rfs_t)$$

where the quantity of DG (dgq_t) is affected by the price of DG (dgp_t) and the price of ethanol ($ethp_t$) along with the RFS dummy variable (rfs_t).

Econometric Model

The first step in estimating the econometric model is determining its structure. The data were entered into Eviews, an econometric estimation software. 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, 1991). 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. An additional dummy variable representing quarter one in the equation would create the problem of perfect collinearity. Compensating for time trend in all three equations was accomplished by incorporating a variable for time.

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.⁵ 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. Serial correlation is when the error terms of different time periods are correlated with one another (Pindyck and Rubinfeld, 1991). 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. Heteroskedasticity occurs in an equation when the error term has an inconsistent variance (Pindyck and Rubinfeld, 1991). The cattle quantity equation was found to have heteroskedasticity. However, it will be subsequently corrected in the estimation. The structure of the three equations is presented below. The equation on cattle quantity:

$$(50) \quad \log(catq_t) = \beta_1 + \beta_2 \log(cornq_t) + \beta_3 \log(dgq_t) + \beta_4 qt2_t + \beta_5 qt3_t + \beta_6 qt4_t + \beta_7 time_t + \beta_8 \log(catq_{t-1}) + \varepsilon$$

⁵ Schwartz criterion penalizes additional coefficients more heavily than the Akaike criterion. Akaike criterion yielded slightly different results than the Schwartz criterion.

The equation on corn quantity:

$$(51) \quad \log(\text{corn}q_t) = \beta_1 + \beta_2 \log(\text{corn}p_t) + \beta_3 \log(\text{eth}p_t) + \beta_4 rfs_t + \beta_5 qt2_t + \beta_6 qt3_t + \beta_7 qt4_t \\ + \beta_8 time_t + \beta_9 \log(\text{corn}q_{t-1}) + \varepsilon$$

The equation on DG quantity:

$$(52) \quad \log(\text{dg}q_t) = \beta_1 + \beta_2 \log(\text{dg}p_t) + \beta_3 \log(\text{eth}p_t) + \beta_4 rfs_t + \beta_5 time_t + \beta_6 \log(\text{eth}p_{t-2}) + \\ \beta_7 \log(\text{dg}q_{t-1}) + \varepsilon$$

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.

$$(53) \quad \log(\text{cat}q_t) = \beta_1 + \beta_2 \log(\text{corn}p_t) + \beta_3 \log(\text{dg}p_t) + \beta_5 \log(\text{eth}p_t) + \beta_6 rfs_t + \beta_7 qt2_t + \\ \beta_8 qt3_t + \beta_9 qt4_t + \beta_{10} time_t + \beta_{11} \log(\text{cat}q_{t-1}) + \beta_{12} \log(\text{corn}q_{t-1}) + \beta_{13} \log(\text{dg}q_{t-1}) + \\ \beta_{13} \log(\text{eth}p_{t-2}) + \varepsilon$$

The next chapter presents and interprets the results of the econometric estimation.

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 5.1.

Table 5.1. Results of weighted two-stage least squares estimation.

	Variables	Coefficient	Standard	t-Statistic	Probability
C(1)	CONSTANT	1.126	0.850	1.33	0.19
C(2)	LOG(CORNQ)*	0.053	0.032	1.63	0.10
C(3)	LOG(DGQ)	-0.015	0.010	-1.55	0.12
C(4)	LOG(CATQ(-1))***	0.807	0.085	9.46	0.00
C(5)	QT2	-0.002	0.015	-0.11	0.91
C(6)	QT3***	0.105	0.028	3.71	0.00
C(7)	QT4***	0.172	0.043	4.04	0.00
C(8)	TIME	0.001	0.001	1.04	0.30
C(9)	CONSTANT***	6.150	0.768	8.01	0.00
C(10)	LOG(CORNP)***	-0.237	0.052	-4.56	0.00
C(11)	LOG(ETHP)	0.037	0.068	0.55	0.59
C(12)	QT2***	-0.804	0.121	-6.63	0.00
C(13)	QT3***	-1.040	0.093	-11.21	0.00
C(14)	QT4***	-1.418	0.060	-23.82	0.00
C(15)	TIME***	0.003	0.001	3.08	0.00
C(16)	RFS*	0.111	0.058	1.92	0.06
C(17)	LOG(CORNQ(-1))***	0.400	0.095	4.23	0.00
C(18)	CONSTANT**	1.309	0.618	2.12	0.04
C(19)	LOG(DGP)	-0.046	0.060	-0.77	0.44
C(20)	LOG(ETHP)	0.066	0.081	0.82	0.41
C(21)	TIME*	0.003	0.002	1.88	0.06
C(22)	RFS	0.015	0.067	0.23	0.82
C(23)	LOG(ETHP(-2))	0.091	0.083	1.09	0.28
C(24)	LOG(DGQ(-1))***	0.909	0.047	19.28	0.00

Table 5.1. (Continued)

Equation: $\text{LOG}(\text{CATQ}) = \text{C}(1) + \text{C}(2)*\text{LOG}(\text{CORNQ}) + \text{C}(3)*\text{LOG}(\text{DDGQ}) + \text{C}(4)*\text{LOG}(\text{CATQ}(-1)) + \text{C}(5)*\text{QT2} + \text{C}(6)*\text{QT3} + \text{C}(7)*\text{QT4} + \text{C}(8)*\text{T}$			
Instruments: $\text{LOG}(\text{CORNP}) \text{LOG}(\text{ETHP}) \text{LOG}(\text{DDGP}) \text{QT2} \text{QT3} \text{QT4} \text{T} \text{RFS}$ $\text{LOG}(\text{CATQ}(-1)) \text{LOG}(\text{CORNQ}(-1)) \text{LOG}(\text{ETHP}(-2)) \text{LOG}(\text{DDGQ}(-1)) \text{C}$			
R-squared	0.894	Mean dependent variable	7.637
Adjusted R-squared	0.883	S.D. dependent variable	0.070
S.E. of regression	0.024	Sum squared residual	0.037
Durbin-Watson statistic	1.951		
Equation: $\text{LOG}(\text{CORNQ}) = \text{C}(9) + \text{C}(10)*\text{LOG}(\text{CORNP}) + \text{C}(11)*\text{LOG}(\text{ETHP}) + \text{C}(12)*\text{QT2} + \text{C}(13)*\text{QT3} + \text{C}(14)*\text{QT4} + \text{C}(15)*\text{T} + \text{C}(16)*\text{RFS} + \text{C}(17)*\text{LOG}(\text{CORNQ}(-1))$			
Instruments: $\text{LOG}(\text{CORNP}) \text{LOG}(\text{ETHP}) \text{LOG}(\text{DDGP}) \text{QT2} \text{QT3} \text{QT4} \text{T} \text{RFS}$ $\text{LOG}(\text{CATQ}(-1)) \text{LOG}(\text{CORNQ}(-1)) \text{LOG}(\text{ETHP}(-2)) \text{LOG}(\text{DDGQ}(-1)) \text{C}$			
R-squared	0.966	Mean dependent variable	8.743
Adjusted R-squared	0.962	S.D. dependent variable	0.494
S.E. of regression	0.097	Sum squared residual	0.599
Durbin-Watson statistic	1.925		
Equation: $\text{LOG}(\text{DDGQ}) = \text{C}(18) + \text{C}(19)*\text{LOG}(\text{DDGP}) + \text{C}(20)*\text{LOG}(\text{ETHP}) + \text{C}(21)*\text{T} + \text{C}(22)*\text{RFS} + \text{C}(23)*\text{LOG}(\text{ETHP}(-2)) + \text{C}(24)*\text{LOG}(\text{DDGQ}(-1))$			
Instruments: $\text{LOG}(\text{CORNP}) \text{LOG}(\text{ETHP}) \text{LOG}(\text{DDGP}) \text{QT2} \text{QT3} \text{QT4} \text{T} \text{RFS}$ $\text{LOG}(\text{CATQ}(-1)) \text{LOG}(\text{CORNQ}(-1)) \text{LOG}(\text{ETHP}(-2)) \text{LOG}(\text{DDGQ}(-1)) \text{C}$			
R-squared	0.989	Mean dependent variable	13.613
Adjusted R-squared	0.988	S.D. dependent variable	1.002
S.E. of regression	0.109	Sum squared residual	0.789
Durbin-Watson statistic	2.013		

*** Indicates significance at the 1% level

**Indicates significance at the 5% level

*Indicates significance at the 10% level

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. All the R-squared values are quite high indicating that the model specifications are appropriate.

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. To begin, the results of the DG quantity equation will be analyzed further. 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. 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 5.2.

Table 5.2. Results of ordinary least squares estimation.

Dependent Variable: LOG(CATQ)				
Variable	Coefficient	Standard Error	t-Statistic	Probability
C***	3.001	0.901	3.33	0.00
LOG(CORNP)	0.042	0.026	1.62	0.11
LOG(ETHP)	-0.031	0.019	-1.63	0.11
LOG(DGP)	-0.034	0.028	-1.21	0.23
QT2***	-0.090	0.034	-2.62	0.01
QT3	0.001	0.028	0.03	0.97
QT4***	0.069	0.017	4.01	0.00
T**	0.001	0.001	2.48	0.02
RFS**	0.034	0.016	2.16	0.04
LOG(CATQ(-1))***	0.618	0.098	6.32	0.00
LOG(CORNQ(-1))*	0.051	0.027	1.89	0.06
LOG(ETHP(-2))	-0.017	0.019	-0.88	0.38
LOG(DGQ(-1))*	-0.033	0.013	-2.50	0.02
R-squared	0.915	Mean dependent variable	7.637	
Adjusted R-squared	0.898	S.D. dependent variable	0.070	
S.E. of regression	0.022	Akaike info criterion	-4.616	
Sum squared residual	0.030	Schwarz criterion	-4.208	
Log likelihood	181.475	Hannan-Quinn criterion	-4.453	
F-statistic	54.049	Durbin-Watson statistic	2.078	
Prob(F-statistic)	0.000			

*** Indicates significance at the 1% level

**Indicates significance at the 5% level

*Indicates significance at the 10% level

The R-squared value for the reduced form equation is 0.915, which indicates that 91.5% of the variation is explained by the explanatory variables. The adjusted R-squared value is 0.898. 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.

CONCLUSION AND IMPLICATIONS

This study was conducted to analyze the direct and indirect effects of ethanol policy on cattle production. The relationships between corn, DG, ethanol, and cattle 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 cattle 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 effects of ethanol policy on cattle production are uncertain in the theoretical model because of the opposite effects policy has on DG and corn prices. A decline in DG prices in the theoretical model may increase cattle production and decrease cattle prices. The opposite is true for an increase in corn prices creating a decline in cattle production and an increase in cattle prices.

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. The RFS may have increased corn yields or 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 effecting cattle production. Econometric results show a possibility of ethanol policy indirectly effecting cattle production through the RFS's influence on corn quantity. Policy makers' intentions with ethanol policy were to increase ethanol consumption and were never 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 on non-targeted markets is important when drafting legislation.

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