THE IMPACTS OF BIOFUEL EXPANSION ON TRANSPORTATION IN INDIANA

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ABSTRACT

Quear, Justin Leonard. M.S., Purdue University, May 2008. The Impacts of Biofuel Expansion on Transportation and Logistics in Indiana. Major Professor: Frank Dooley

The U.S. biofuels industry has rapidly expanded since 2005, growing in Indiana from one ethanol plant in 2006 to six in 2008, with an additional six scheduled to open by 2010. In turn, this expansion has many ramifications on transportation within Indiana.

The objective of this thesis is to determine how entry of biofuel plants affects inbound and outbound transportation flows of corn, soybeans, DDGS, and ethanol at the county level in Indiana. To observe the effects of biofuel expansion, three time periods were examined: a baseline in 2006, short term adjustments in 2008, and long term adjustments in 2010. Linear programming (LP) models allocated flows between production and consumption points for corn, soybeans, DDGS, and ethanol for each time period. Output from the LP models was then used in a spreadsheet model to estimate truckloads, one-way annual truck miles (VTM), average length of haul (LOH), and rail carloads for each commodity.

Truck traffic in Indiana associated with grain, ethanol, and DDGS movements increase by 14.0 million VTM, or 45.3 percent, due to biofuel expansion. The major drivers of increased truck VTM are outbound shipments of ethanol, corn to ethanol

plants, and soybeans to oil crushers, up 12.4, 5.9, and 2.0 million miles, respectively. In contrast, corn from farms to elevators fall by 2.7 million miles, while corn from elevators fall 2.2 million miles.

Most of this change occurs in counties with biofuel plants. Truckloads of grain hauled to elevators decline between each period as more grain is shipped to biofuel plants. Compared to elevators, the average LOH for grain to biofuel plants is farther by approximately 10 miles per load.

Rail carloads of corn leaving Indiana decrease by 40 percent, but much of this decline is offset by increases in outbound carloads of ethanol and DDGS. This means that the reduction in grain being transported by rail is partially offset by the increase in rail shipment of ethanol and DDGS. Additionally, while transportation of grain by rail is seasonal, ethanol and DDGS most likely will generate steady year round traffic.

CHAPTER1: INTRODUCTION

1.1 Overview

Since 2005, biofuel (especially corn based ethanol and soy-biodiesel) plant construction has seen a dramatic increase throughout the United States. The state of Indiana alone has gone from one ethanol plant in 2006 to six in early 2008, with an additional six plants planned to begin producing by 2010 (ISDA 2008). The growth in this industry can be partially attributed to increasing prices paid at fuel pumps, which have fueled political support to reduce imports of crude oil. In 2006, the United States imported 3.7 billion barrels of crude oil, of which, nearly half came from the Organization of Petroleum Exporting Countries (OPEC) (EIA 2008a). Additionally, biofuels have been viewed as a mechanism for rural economic development, especially in the Midwest states of Iowa, Illinois, Nebraska, Minnesota, Kansas, Wisconsin, Missouri, and Indiana. These states produce most of the nation's corn and soybeans, with US production around 40 percent of the world's total production.

Growth in the biofuel industry has affected several related industries, most notably agriculture. Production of biofuels from corn and soybeans provides new product market opportunities for agricultural commodities, with the potential to increase farm revenues or expand the productive capacity of existing cropland, thus bringing economic benefits to rural communities. One effect of biofuel expansion already occurring is an increase in commodity prices. While higher commodity prices might spur rural economic development, they have also increased production costs for livestock producers as well as grain based food processing plants. Additionally, grain producers are also experiencing higher prices as increases in grain production are leading to higher prices for key inputs such as land, nitrogen, and seed. As more biofuel plants are constructed, it can be expected that commodity prices will remain high and become more volatile (Tyner et al. 2008).

Historically, corn and soybeans have been transported from production areas to livestock, food processing plants, biofuel plants, or country elevators. Transportation requirements differ among each of these grain utilization types. As additional biofuel plants come online, more corn will be demanded by these plants. This will not only affect the distribution of grain among each demand type, but also will affect how grain is transported. One possibility is that grain produced in an area where a biofuel plant is introduced will be shipped longer distances to the plant rather than being transported shorter distances to local country elevators. This also means that less corn will be available for long haul shipment by unit trains or barge. Additional ethanol plants also mean that more ethanol and distillers dried grain with solubles (DDGS), a co-product of ethanol production, will enter the area's transportation network. Changes in transportation flows due to biofuels will affect other industries as well. If additional truck traffic occurs and transportation routes change, additional damage to roadways not accustomed to heavy truck traffic is possible.

This is one of the first studies to examine the impacts of biofuel expansion on transportation requirements. Because agriculture, biofuel, and transportation industries vary among different geographic regions in the United States, the focus of this study was limited to the state of Indiana. Transportation flows of grain, biofuels, and co-products will remain large in volume but will be changing as more biofuel plants come online. However, the magnitude of these changes is unclear, and thus, this study will help answer questions regarding changes in truck and rail traffic and policy implications as the biofuel industry in Indiana expands. These changes lead to important public policy questions as to how the state of Indiana can best nurture and develop the biofuel industry as it continues to grow.

1.2 Objective and Approach

The objective of this thesis is to determine how entry of biofuel plants affect inbound and outbound transportation flows of corn, soybeans, DDGS and ethanol at the county level in Indiana. To achieve this, transportation flows of corn, soybeans, ethanol, and DDGS will be examined in detail.

The first step is to build a baseline model using Indiana production and consumption data for corn, soybeans, ethanol, and DDGS for 2006. Production includes corn and soybean production, ethanol production, and DDGS production. Corn consumption includes livestock, food processing, ethanol, and grain elevators. Soybean consumption includes crushing facilities (including biodiesel plants) and grain elevators. Ethanol consumption is by gasoline blending terminals, while DDGS consumption is feeding livestock. Transportation linear programming (LP) models estimate commodity flows between each production and consumption point such that transportation costs are minimized. Output from LP models is used as an input in a spreadsheet model to calculate transportation requirements.

The second step uses the same linear programming models from goal one, but with data from 2008 and 2010. This requires forecasting production and consumption for corn, soybeans, ethanol, and DDGS. Once data are forecast and used within the models, output from the spreadsheet model represents transportation requirements for each of these years that can be compared to the 2006 baseline model.

The third step is to evaluate changes between each time period. Output from the spreadsheet models from each year includes truckloads, vehicle trip miles traveled by truck (VTM), average length of haul (LOH), rail car loads, and shifts between truck and rail transport between production and consumption points. Because biofuel production in Indiana is expanding rapidly during this time and is the main adjustment in terms of production and consumption, differences between each time period indicate changes in transportation requirements due to biofuel expansion.

1.3 Organization

The remaining section of this chapter is a brief review of literature focusing on the transportation sector of the biofuel industry. In Chapter 2, an extensive overview of the biofuels industry is provided including information about legislative history, ethanol production capacity and demand, ethanol demand for corn, and DDGS supply and demand. The data, assumptions, and model development are detailed in Chapter 3. Empirical results from all models are reported in Chapter 4. In Chapter 5, conclusions for the biofuels industry are reported, which can be used as a planning tool for 2010. It is likely that local transportation planners, ethanol producers and consumers, farmers, and grain elevator operators will be most interested in the conclusions. Suggestions for future research are also discussed in Chapter 5.

1.4 Literature Review

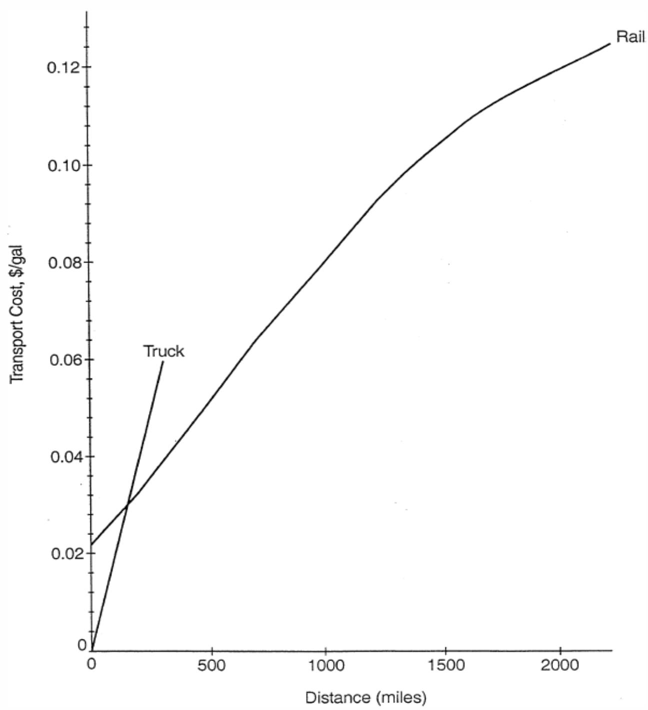
The remainder of this chapter will examine literature focusing on transportation issues within the corn based ethanol industry. Published literature examining the ethanol industry is very limited. This industry has only recently experienced rapid growth causing new transportation issues to arise. This section focuses on two sources that address the transportation segment of the ethanol industry.

As the ethanol industry expands, it is possible that transportation flows of corn, ethanol, and DDGS will be altered. A USDA publication by Denicoff (2007) addresses possible transportation issues likely to occur as this industry expands. Denicoff reports that approximately 98% of corn supplied to ethanol plants is shipped via truck from within a 50 mile radius of the plant. Thus, corn shipments by truck will increase when an ethanol plant is constructed. Denicoff also suggests that as more corn is utilized by ethanol plants, corn transported by rail likely will decline.

In 2006, 60 percent of the nation's ethanol and much of the DDGS produced was shipped by rail (Denicoff 2007). Although corn shipments of corn by rail are expected to decline, ethanol and DDGS rail shipments will increase, which will partially offset the decrease in carloads of corn being shipped. However, because of an interdependence of corn for fuel versus feed and food and the unknown shifts of corn among these uses, the total impact on the railroad industry remains uncertain.

This uncertainty is compounded by the lack of rail receiving capabilities by many destination points for ethanol and DDGS.

Denicoff (2007) reports that transportation costs are the third highest cost for an ethanol producer behind feedstock and energy costs. A study by Gallagher et al. (2000) compares truck and rail transportation costs associated with shipments of ethanol. This analysis indicates that rail transport of ethanol is most economical for shipments exceeding approximately 140 miles (Figure 1.1). However, for states with less rail infrastructure, the distance at which transport by rail and truck cost the same will increase. Likewise, for states with more rail infrastructure, this distance might decline (Gallagher et al. 2000).



Source: Gallagher et al. (2000).

Figure 1.1: Estimated Transport Costs for Ethanol: Truck and Rail

The ability of ethanol plants and demand locations to ship and receive unit trains of ethanol will also play a significant role in transportation costs (Denicoff, 2007). This will also be a factor in determining the distance at which rail shipments become more economical than truck shipments. Denicoff reports that on average, a unit train carrying ethanol can make 30 turns per year compared to 12 for a single car. Additionally, single car rates can be as much as four times higher than unit train rates (Denicoff, 2007).

CHAPTER 2: INDUSTRY BACKGROUND OVERVIEW

The rapid growth of ethanol production in Indiana and the US is leading to far-reaching changes in grain marketing and transportation. Federal legislation is a key driver underlying this change, with policy changes since 2005 leading to a rapid expansion in industry capacity. In turn, this expansion has affected markets for corn, other crops and DDGS. After investigating national trends for biofuels expansion, impacts are considered for Indiana. This chapter will discuss the legislative history, US ethanol demand and capacity, corn production, and DDGS. Information in this chapter is based on a literature review, focusing on publications since 2002.

2.1 Legislative History

The growth of the biofuel industry has been closely tied to agricultural and energy policies since 1978. Over the past 30 years, federal policy with respect to biofuels has included tax exemptions, production credits, and tariffs on ethanol imports. In addition, many states have provided subsidies for ethanol production, seeking to promote development of ethanol industries within their boundaries.

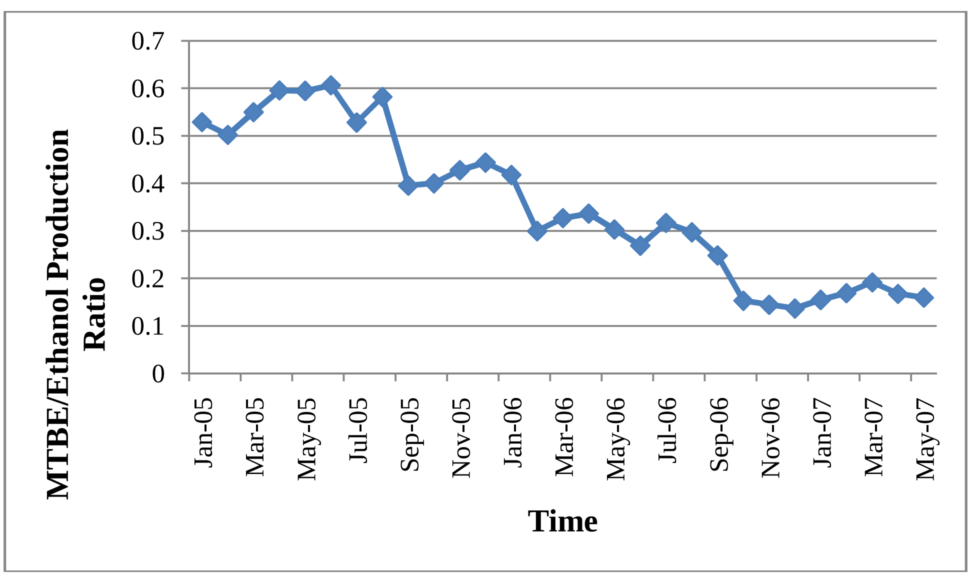
The Energy Tax Act of 1978 created a 4 cent per gallon tax exemption on all gasoline containing at least 10 percent ethanol (E10). This is equivalent to a 40 cent per gallon subsidy on ethanol. Since then, tax exemptions have fluctuated between 40 and 60 cents per gallon of ethanol, and currently is in the form of a 51 cent per gallon blender tax credit (Table 2.1). Initially, subsidies for ethanol were justified as both a means of rural economic development (by increasing a local demand for corn) and for producing energy domestically from renewable sources (Duffield 2006).

Table 2.1: History of Biofuels Federal Legislation, 1978 to 2007

Year	Act	Key Features
1978	Energy Tax Act of 1978	$0.40 per gallon of ethanol tax exemption on the $0.04 gasoline excise tax
1980	Crude Oil Windfall Profit Tax Act and the Energy Security Act	Promoted energy conservation and domestic fuel development
1982	Surface Transportation Assistance Act	Increased tax exemption to $0.50 per gallon of ethanol and increased the gasoline excise tax to $0.09 per gallon
1984	Tax Reform Act	Increased tax exemption to $0.06 per gallon of gasoline
1988	Alternative Motor Fuels Act	Created research and development programs and provided fuel economy credits to automakers
1990	Omnibus Budget Reconciliation Act	Ethanol tax incentive extended to 2000 but decreased to $0.54 per gallon of ethanol
1990	Clean Air Act amendments	Acknowledged contribution of motor fuels to air pollution
1992	Energy Policy Act	Tax deductions allowed on vehicles that could run on E85
1998	Transportation Efficiency Act of the 21st Century	Ethanol subsidies extended through 2007 but reduced to $0.51 per gallon of ethanol by 2005
2004	Jobs Creation Act	Changed the mechanism of the ethanol subsidy to a blender tax credit instead of the previous excise tax exemption. Also extended the ethanol tax exemption to 2010.
2005	Energy Policy Act	Established the Renewable Fuel Standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012.
2007	Energy Independence and Security Act	Extended Renewable Fuel Standard requiring 36 billion gallons of renewable energy be consumed by 2022.

Source: North Dakota Chamber of Commerce (2006) and RFA (2008a)

With the passage of the Clean Air Act in 1990, ethanol was also viewed as an oxygenate for gasoline with environmental benefits as compared to methyl tertiary-butyl ether (MTBE). The Energy Policy Act of 2005 lacked provisions shielding MTBE manufacturers from water contamination lawsuits, which in effect caused the usage of MTBE to decrease dramatically. The MTBE/Ethanol production ratio is simply MTBE production divided by ethanol production (Figure 2.1). A ratio value of over .5 signals more MTBE is being produced than ethanol, thus more is being used as an oxygen additive. In contrast, a ratio value of less than .5 signals more ethanol is being produced than MTBE. As recent as August 2005, more MTBE was being produced than ethanol. Since then ethanol has largely replaced MTBE. Because a primary use of each is as an oxygenate, shifts in production are a means for examining shifts in consumption. The Energy Independence and Security Act of 2007 also lacked provisions protecting MTBE manufacturers.

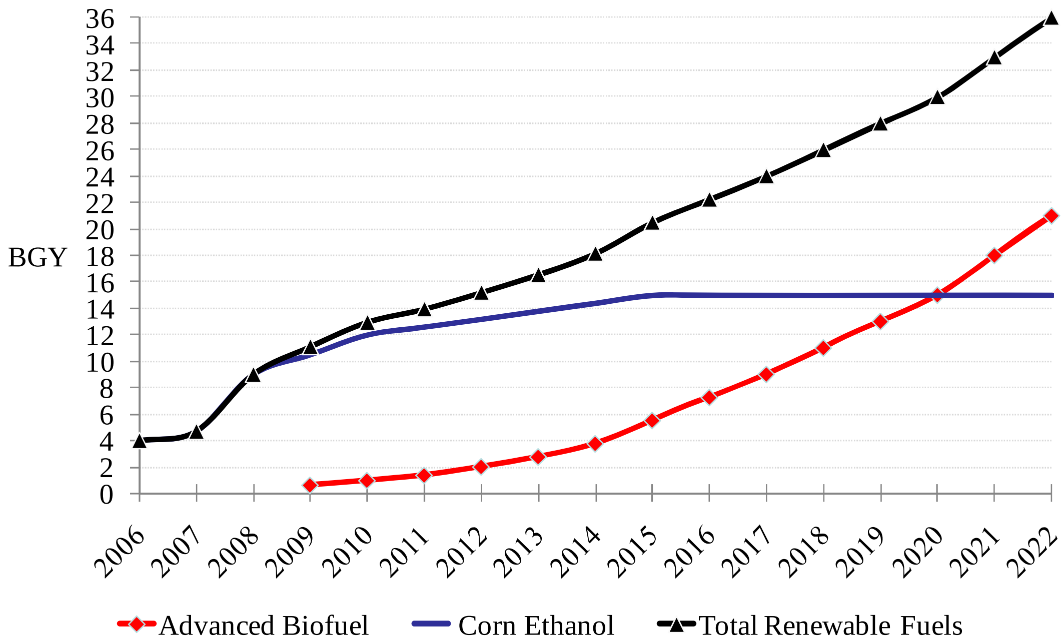


Source: Energy Information Administration, DOE (2007a)

Figure 2.1: Gasoline Oxygenate Production Ration (MTBE/Ethanol)

The Energy Conservation Reauthorization Act of 1998 amended the Energy Policy Act to allow biodiesel to qualify as a renewable fuel to meet public utility alternative fuel requirements. In 2005, the biodiesel blenders' tax credit was established, providing $1.00 per gallon credit for agri-biodiesel produced from virgin oils, either from crops or animal fats. A small biodiesel producer tax credit of $0.10 per gallon up to 15 million gallons per year is available for producers of biodiesel who annually produce less than 60 million gallons.

In 2005, the Renewable Fuel Standard (RFS) mandated a minimum amount of renewable fuel that must be consumed in the United States for the first time. The volume of renewable fuel required to be blended into gasoline started at 4.0 billion gallons in calendar year 2006 and was to increase to 7.5 billion gallons by 2012. In December of 2007, the RFS was amended in the Energy Independence and Security Act which mandated that 36 billion gallons of renewable energy be consumed by 2022 (Figure 2.2). Of this, 15 BGY is to be from corn based ethanol, while the remaining 21 BGY is to be from advanced biofuels. The latter includes 1 BGY of biodiesel and 20 BGY of other advanced biofuels, mainly cellulosic ethanol.



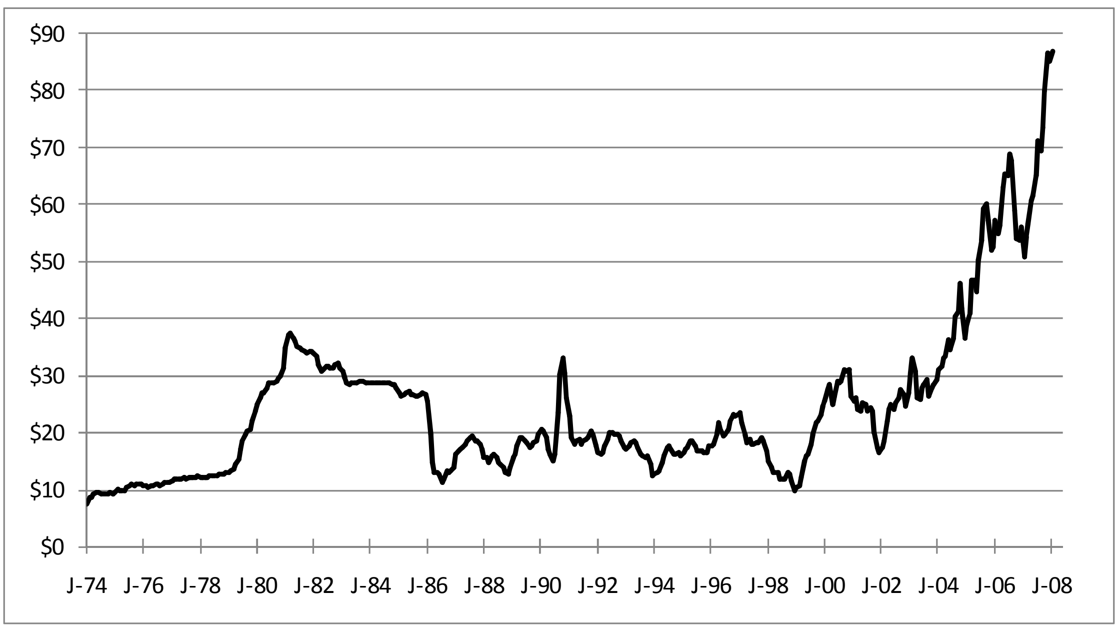
Source: RFA (2008a)

Figure 2.2: 2007 Renewable Fuels Standard Requirements, 2006-2022

2.2 U.S. Ethanol Capacity and Demand

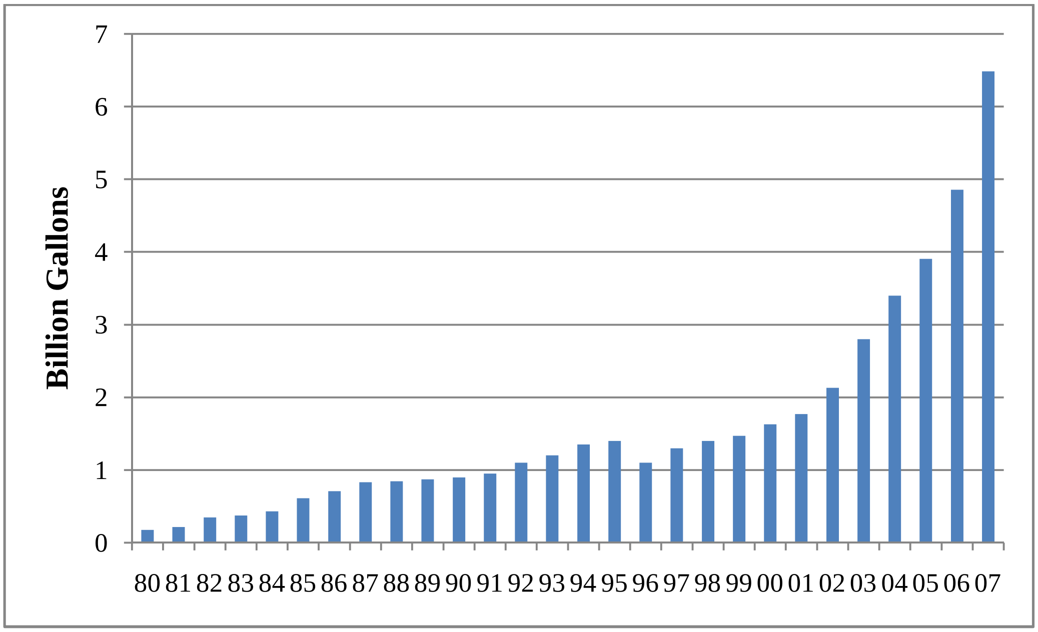
In the late 1970s, ethanol was viewed as an important domestic alternative to gasoline and the market power of OPEC. However, when oil prices declined in the mid-1980s, so did the idea of ethanol as a gasoline alternative. Thus, from 1978 to 2004, subsidies were the primary factor driving the ethanol markets and production (Sarmiento and Wilson, 2007). The oil price increases since 2004 have once again led to legislation supporting ethanol as a gasoline alternative which is apparent by the extension of the RFS in the Energy Independence and Security Act of 2007. However, perhaps as important to the renewed interest in ethanol have been state level bans on MTBE as environmental degrading characteristics were realized and a move away from MTBE due to a lack of federal government protection against liability suits.

From 1982 to 2002, the oil price per barrel was relatively steady, hovering between $10 and $30 per barrel (Figure 2.3). Ethanol production remained steady at around 1 billion gallons per year during this same time (Figure 2.4). Since 2004, oil prices have significantly increased moving above $100/barrel in March of 2008 (EIA 2008b). While crude oil prices increased during this time, ethanol production more than doubled from 2.1 to 6.5 billion gallons per year.



Source: Energy Information Administration (2007b)

Figure 2.3: U.S Refiner Acquisition Cost of Crude Oil ($/BBL), 1975 to 2007

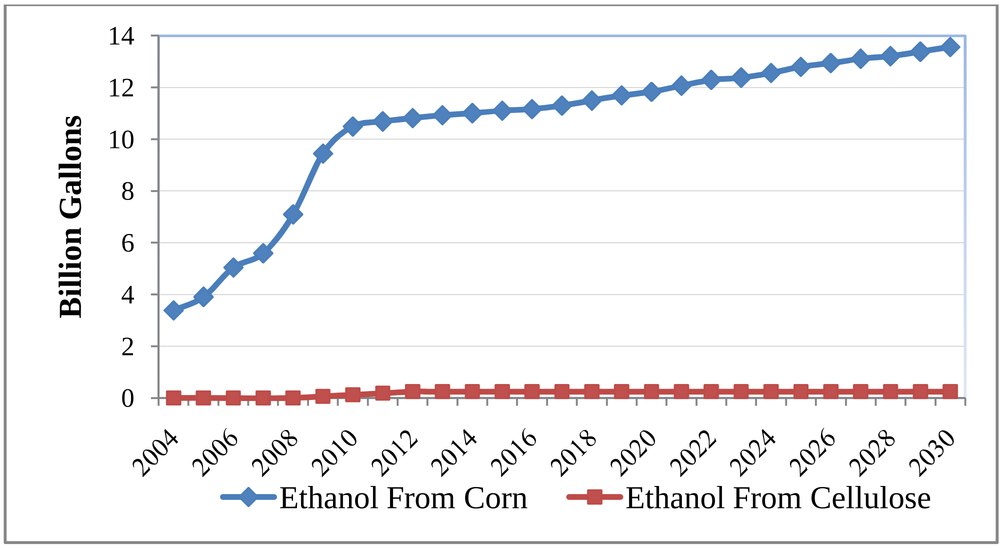


Source: Renewable Fuels Association (2008b)

Figure 2.4: US Ethanol Production, 1980 to 2007

Ethanol production capacity is expected to continue its rapid expansion over the next few years. Both the United States Department of Agriculture (USDA) and the Department of Energy (DOE) have similar projected ethanol capacities through 2017. The Energy Information Administration of the DOE has projected ethanol production through 2030 for both corn based ethanol and cellulosic based ethanol (EIA 2007a). USDA projections are for 10 years.

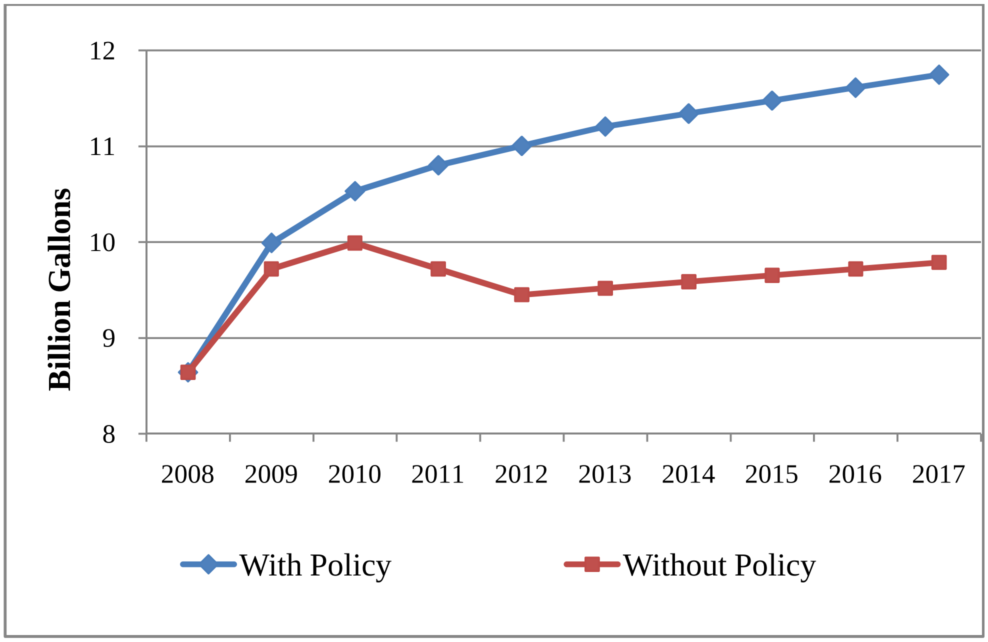
In 2007, DOE projected ethanol production to rapidly expand from 2007 through 2010, at which time it will reach 10.5 billion gallons (Figure 2.5). Over the next 20 years it will then steadily expand by 3.1 billion gallons to reach 13.6 billion gallons in 2030. Based on current technology, DOE projections only see cellulosic ethanol production of 0.25 billion gallons in 2030. Thus, this forecast does not take into consideration the possible scientific breakthrough that would make production of cellulosic ethanol on a commercial scale possible. This forecast also does not take into consideration the Energy Independence Security Act. The DOE also projects imports to increase from .15 billion gallons in 2004 to .83 billion gallons by 2030.



Source: Energy Information Administration (2007a)

Figure 2.5: DOE Projected Ethanol Production from Corn and Cellulose

In 2007, the United States Department of Agriculture forecasted ethanol production from corn through 2017 for two different scenarios. First, ethanol policy is assumed to remain unchanged through 2017. Alternatively, policy for ethanol and biodiesel tax credits and tariff subsidies are assumed to end in 2008 with no policy enacted through 2017 (US Department of Agriculture, 2007a). Under the assumption that policy remains unchanged, ethanol production is projected to increase from 8.6 billion gallons in 2008 to 11.75 billion gallons in 2017, or roughly 175 MGY after 2010 (Figure 2.6). Production is expected stay around 10 billion gallons assuming that federal ethanol policy ends. The USDA does not make projections for cellulosic ethanol productions, stating it is at least five years before it will be produced commercially (US Department of Agriculture 2007a).



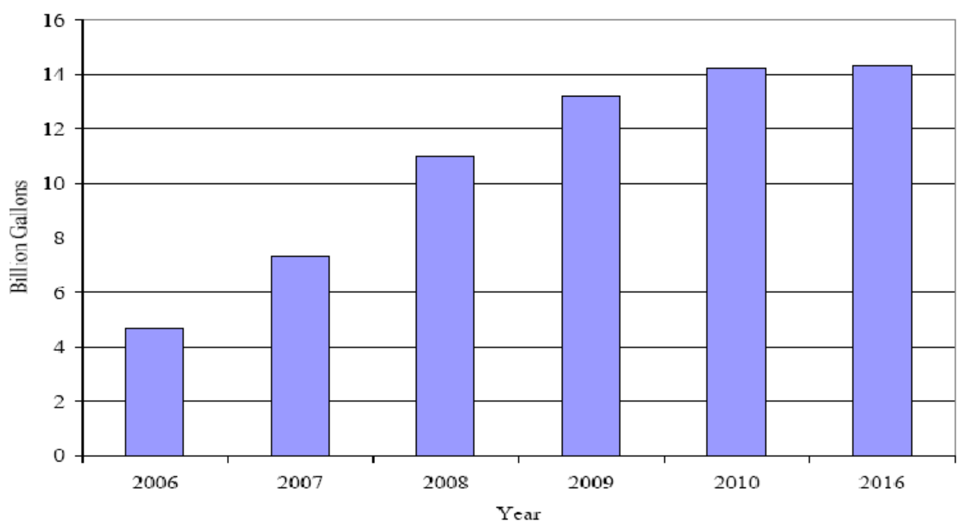
Source: USDA Foreign Agriculture Service (2007)

Figure 2.6: USDA Ethanol Production Projections

The Center for Agricultural and Rural Development (CARD) at Iowa State University has also forecasted ethanol production from corn and the effects it will have on grain and livestock markets through 2017 in a May, 2007 report (Iowa State University 2007). This study assumes legislative policy in May 2007 remains the same and that cellulosic ethanol is not competitive under current conditions and does not become competitive in the time period examined. An additional assumption is that possible transportation issues associated with ethanol expansion are solved. Forecasts are done under three different scenarios:

1. High oil prices combined with widespread adoption of flexible fuel vehicles
2. A repeat of the drought of 1988 combined with a 14.7 billion gallon ethanol mandate.
3. Removal of an additional seven million acres from the Conservation Reserve Program

The CARD report's baseline projection forecasts that ethanol production from corn will increase through 2010 to slightly above 14 billion gallons and then will level off due to price decreases from an increase in production. The increase in production will come from plants that are under construction as of 2007 and will be online by 2010. Ethanol production will remain relatively constant through 2016 (Figure 2.7).



Source: Iowa State University, CARD Report (2007)

Figure 2.7: Baseline Projected US Ethanol Production from Corn

Under the first assumption that oil will increase by $10/barrel and there are no E85 bottleneck effects, ethanol production is projected to reach 29.7 billion gallons by 2017; however, this scenario is very unlikely (Iowa State University 2007). Under the second assumption that a drought causes a short crop and high ethanol mandates remain the same, ethanol production is projected to reach 14.7 billion gallons. Under the third assumption that seven million acres are taken out of the Conservation Reserve Program, ethanol production is projected to reach 15.3 billion gallons.

It is very unlikely that only one of the scenarios will actually take place in the near future. Because of this, the authors of the CARD report estimate that 14.8 billion gallons will be produced by 2011 and that production will level off and remain relatively constant (Iowa State 2007). To arrive at this production level, it is assumed that a modest increase in corn acreage will occur as well as an increase in corn price to approximately $3.40/bushel. Most of the corn acreage increase will come from soybean acres.

All three reports were written before the Energy Independence and Security Act of 2007 and do not account for provisions included in this legislation. Results from all three reports predict an increase in ethanol production through 2010 that will level off between 11 and 15 billion gallons by 2017 (Table 2.2). The USDA and DOE reports both forecast similar annual increases through 2017. The DOE report forecasts that production will then gradually increase to near 14 billion gallons after 2017. The CARD report forecasts a more rapid growth that levels off in 2010 rather than after 2017 at slightly above 14 billion gallons with little or no growth after that time. A similarity among all three reports is that production is forecast to level off by 2010, at a level near the amount necessary to fulfill a 10% blend of all gasoline.

Table 2.2: Comparison of Forecast Reports (Billion Gallons)

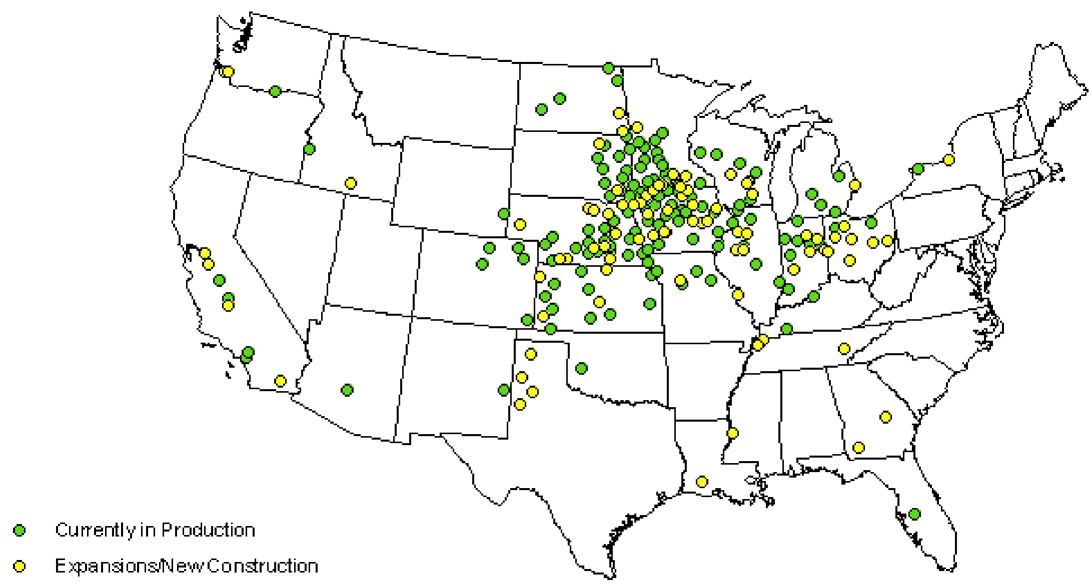
Source	2007	2008	2009	2010	2017
USDA	5.6	8.6	9.9	10.5	11.7
EIA	5.6	7.1	9.4	10.5	11.3
CARD	7.2	10.9	13.2	14.2	14.8

Sources: Iowa State University CARD Report (2007), USDA Foreign Agriculture Service (2007), and Energy Information Administration (2007a)

According to Ethanol Producer Magazine's website, as of March 2008, the ethanol industry consists of 145 plants with a total capacity of 8.0 billion gallons per year. An additional 56 plants are currently under construction, adding 4.35 BGY of capacity, which will lead to a total capacity of 12.4 BGY by the end of 2008. Thus, the ethanol industry appears poised to reach governmental projections. Industry capacity numbers are slightly higher at American Coalition for Ethanol's website and Renewable Fuels Association's website, two additional trade associations (Table 2.3). Iowa State University's CARD has created a geographical distribution of ethanol plants both under construction and in production as of January 2008 (Figure 2.8).

Table 2.3: Ethanol Capacity and Expansion, November 2007

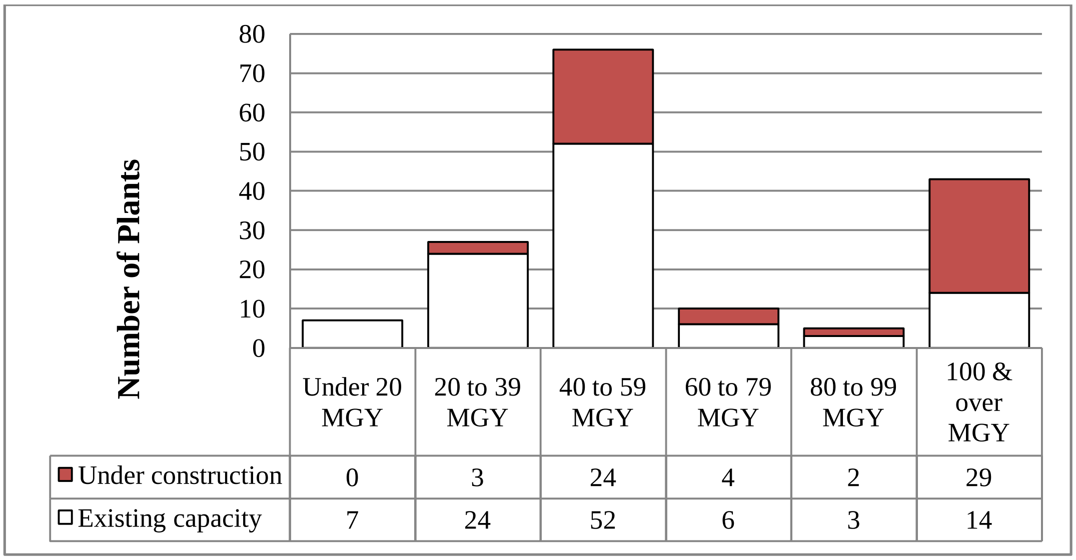
Reporting Association	Web Address	Current Capacity		Expansion	
		Number of Plants	Capacity (MGY)	Number of Plants	Capacity (MGY)
CARD	www.card.iastate.edu/research/bio	137	7,630	70	5,740
Renewable Fuels Assn	www.ethanolrfa.org/industry/locations	131	7,023	82	6,452
Ethanol Producer	ethanolproducer.com/plant-list.jsp	138	7,166	54	4,167
American Coalition for Ethanol	www.ethanol.org/index.php?id=37	135	7,005	75	5,503



Source: Iowa State University CARD (2008)

Figure 2.8: Geographical Distribution of Ethanol Plants

Newer plants tend to be larger on average than older plants. A typical plant constructed before 2006 had a capacity around 50 million gallons per year (MGY) with 80% of all older plants being less than 60 MGY (Figure 2.9). In contrast, half of the plants under construction will have 100 MGY or more of capacity. One implication is that the newer plants will have larger draw areas for inbound transportation.



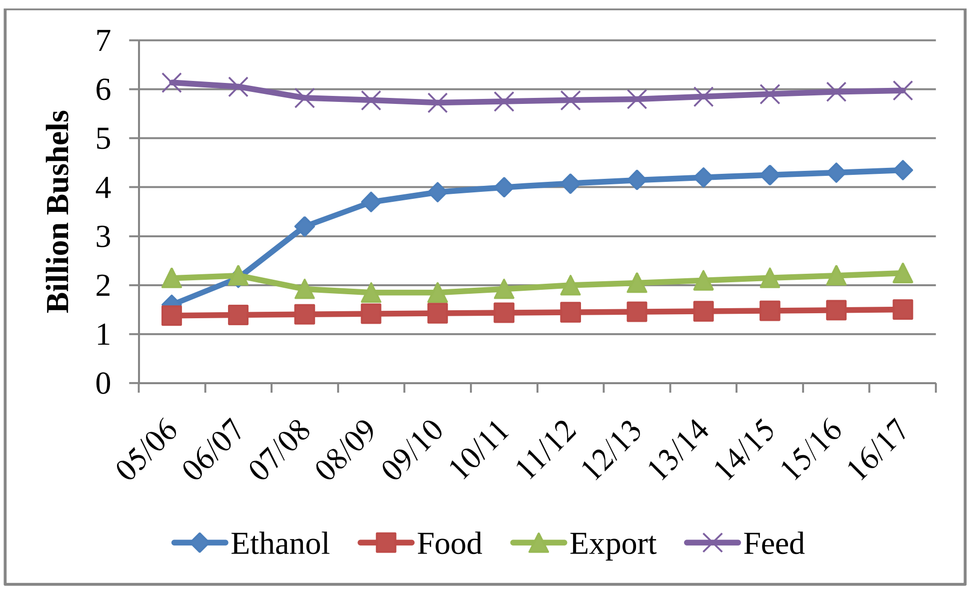
Source: Ethanol Producer Magazine (2007)

Figure 2.9: Size Distribution of Ethanol Plants, 2007

2.3 Ethanol Corn Demand

The demand for corn swells with increases in production of ethanol. In 2006, about 1.9 billion bushels of corn were used for ethanol production, or about 17 percent of the 2006 U.S. corn crop (US Department of Agriculture, 2007a). The renewable fuels standard requires 15 billion gallons of ethanol to be produced from corn in 2015 thus, corn utilization for ethanol will certainly increase. Future effects of this growth are unknown but could possibly include increasing corn prices, an expansion in corn acreage, less corn fed to livestock, or less corn available for export. National planted acres of corn increased by 19% from 2006 to 2007 which signal that an increase in corn production has already occurred (NASS 2007). However, preliminary projections for 2008 signal a decrease in corn acres. Combined, these changes in market conditions have lead to greater price volatility (Tyner, Dooley, Hurt, and Quear 2008).

USDA long range forecasts project total usage of U.S. corn to rise from 12.5 billion bushels in 2005/06 to 17.5 billion bushels a decade later (Figure 2.10). Feed and export use are constant at around 6 and 2 billion bushels, respectively. In contrast, ethanol utilization of corn more than, going from 2 to 4 billion bushels while food utilization has a slight decline but then recovers by 2017.

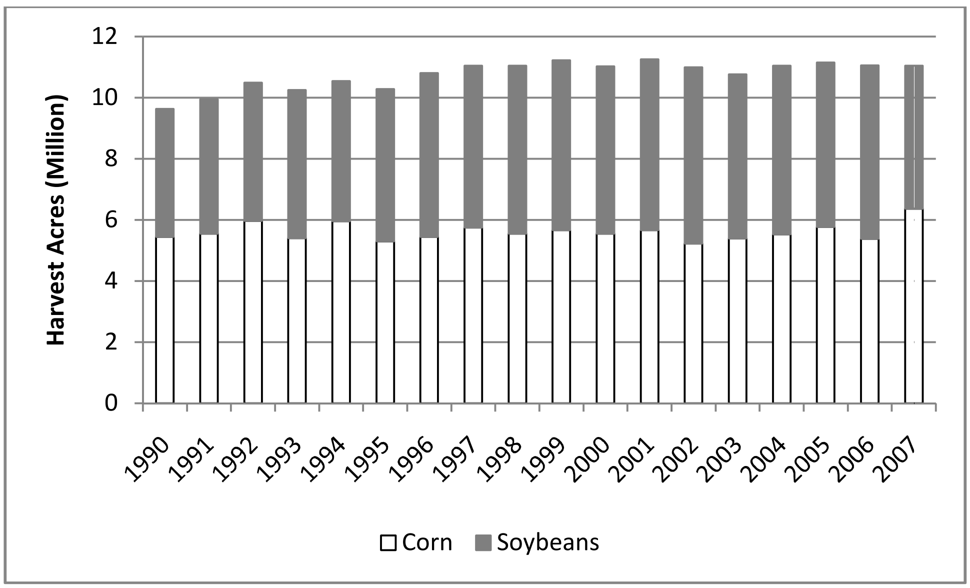


Source: Economic Research Services, USDA (2007a)

Figure 2.10: Corn Usage for Ethanol, Food, Export and Feed, 2005-06 to 2016-17

Corn and soybean production are interrelated. Throughout much of the past decade corn and soybean harvested acres have seen little variability (Figure 2.11). In

2007, this trend changed with an increase in corn acres and decrease in soybean acres. This change can be explained partially by the increase in ethanol demand as well as a swell in corn price. However, soybean prices have also increased through February of 2008 which will likely affect acres of corn and soybeans in 2008. Because of increasing prices and volatility in both markets, forecasting harvested acres into the future has become very difficult. Thus, this study assumes that historical production patterns from 2000 to 2006 hold through the time period examined.



Source: USDA, National Agriculture Statistic Service (2008)

Figure 2.11: Corn and Soybean Harvested Acres in Indiana, 1990-2007

2.4 DDGS Supply and Demand

The production of ethanol creates a co-product called distillers dried grain with solubles (DDGS), which is commonly sold as a livestock feed source. DDGS is produced after the starch portion of corn is converted to ethanol and carbon dioxide leaving components of protein, fat, fiber, vitamins and minerals which are then concentrated and dried to produced DDGS (RFA 2007). DDGS is more valuable as a feed in ruminant animals (cattle and sheep) mainly because of the high fiber content that cannot be digested by mono-gastric livestock (swine and poultry) (Urbanchuk 2003). The percentage of the DDGS as an ingredient in livestock diets varies among species (Table 2.4). Sheep and beef cattle rations can have up to 25%, dairy cattle can consume up to 20% DDGS, while poultry and hogs can only consume 10% of DDGS in a ration (Urbanchuk 2003).

Table 2.4: DDGS Inclusion Rates by Specie, 2003

Specie	Maximum DDGS Rate
Sheep	25%
Beef Cattle	25%
Dairy Cattle	20%
Swine	10%
Poultry	10%

Source: Urbanchuk (2003)

When DDGS is introduced into a feed ration, corn consumption decreases. A study from Iowa University's Iowa Civic Analysis Network has calculated the amount of corn displaced with a DDGS inclusion rate of 10 percent and 20 percent using a corn based feed mix model. The base diet is a 2,000 pound feed ration that includes no DDGS and 1,463 pounds of corn. When DDGS becomes 10 percent of the diet, the amount of corn decreases by 162 pounds to 1,301 pounds of corn which is a 11.1 percent reduction. Likewise, when DDGS is 20 percent of the diet, corn decrease from 1,463 to 1,201 pounds which is a difference of 262 pounds or a 17.9 percent decrease.

Advantages of DDGS as a feed ingredient include high protein content, high available phosphorus, and substitutability meaning that it can easily partially replace other feed ingredients such as corn and soybean meal. However, DDGS has its disadvantages as well, including that there is a limit as to the quantity that different species are able to be fed, high nitrogen uptake which has a negative effect on meat quality, high oil content, consistent nutrition composition, quality consistency, transportation, and market volumes (McElroy 2006).

The lack of consistency in DDGS production among differing plants and batches within a particular plant is seen as a key detriment. Variations in nutrient content cause livestock producers to use less DDGS as an ingredient. For example, fat content has been found to range from 1% to 30%, protein from 24% to 29%, and moisture 9% from 15% (McElroy 2006).

Transportation of DDGS has also become a major issue. The Burlington Northern Santa Fe and Union Pacific, two of the nation's largest railroads, have banned hauling DDGS in their own equipment, although they will transport DDGS loaded in shipper owned cars (Ileleji 2006). Transportation difficulties arise because DDGS is difficult to remove from hopper rail cars due to caking occurring during transport. Segregation of particles also occurs during handling and transportation, adding to the already existing quality and consistency issues.

Transportation of DDGS to livestock producers within Indiana also has many issues. Livestock production is dispersed rather than being concentrated near ethanol production (Ileleji 2006). Thus, DDGS will have to be transported across the state if producers want to use it as a feed source. Also, few livestock farms can receive

DDGS by rail, meaning that intrastate transportation would likely require truck transportation.

Historically, DDGS has been an important source of revenue for an ethanol plant. In 2003, profit margins for a 40 million gallon ethanol plant found 15 to 20 percent of the plant's revenue from DDGS sales (Tiffany and Eidman, 2003). Due to the increase in ethanol prices coupled with payments through tax incentives, the percent of plant revenue in 2007 from DDGS sales is approximately 10% (McElroy 2006). As ethanol production is expected to continue to expand in the near future, the impact of revenue percentage for DDGS remains uncertain.

Conservatively, a bushel of corn produces 2.79 gallons of denatured ethanol and 18 pounds of DDGS (Mosier and Klein, 2006). Thus, 3,333 tons of DDGS are produced for every million gallons of ethanol. As of January 1, 2008, there were 6 ethanol plants in production in Indiana (South Bend, Linden, Clymers, Rensselaer, Portland, Marion), with a total of 515 MGY capacity. Combined, they would produce approximately 1.7 million tons of DDGS annually. Given aforementioned nutritional constraints, an upper limit for Indiana livestock feeders is approximately 1.5 million tons (Urbanchuk 2003).

As more plants come into production, the amount of DDGS produced will also increase. If total industry capacity in Indiana reaches 1 billion gallons, more than 3.3 million tons of DDGS will be available for in-state consumption. Thus, as much as 1.8 million tons of DDGS will be transported to out-of-state livestock producing areas, such as the Southeast and Southwest as well as to export market channels.

2.5 Conclusions

The major changes and shifts in grain production, grain marketing, and other related fields due to expansion in the biofuels industry are especially evident in Indiana. It is likely that Indiana will experience more growth in the biofuel industry through 2010 than other regions of the Midwest because of limited production capacity before 2006. In addition, Indiana is better located to serve regional truck markets surrounding the state with ethanol than western producing states. These factors suggest that changes in Indiana transportation requirements may differ from those in western Corn Belt States

CHAPTER 3: DATA AND MODEL DEVELOPMENT

This chapter discusses the data sources, key assumptions, and development of the model. Data for the model are acquired at the county level for the state of Indiana. Production data are collected for corn, soybeans, ethanol, and DDGS. Demand data are collected for livestock numbers, food processing plants, soybean crushing facilities, ethanol plants, and grain elevators. The data are used to develop a model that determines transportation flows in Indiana between each supply and demand point. Data are collected and a model developed for three time periods which include 2006, 2008, and 2010. The 2006 model is the baseline model which can be compared with a short term adjustment model (2008) and a longer term adjustment model (2010).

3.1 Data

Corn and soybean production data for all three periods are needed. For 2006, county level production data are obtained from USDA's National Agriculture Statistics Service (NASS) including yield, harvested acres, and total production.[1] Similar data for 2008 and 2010 are forecasts. Harvested acres for 2008 and 2010 are

[1] Indiana county level data is available on "Statistics by State" portion of NASS website at http://www.nass.usda.gov/Statistics_by_State/Indiana/index.asp. Once on the Indiana NASS page, county level data are available under "Quick Stats." Data for 2006 are not available for Jefferson County but were available from 2000-2005. Thus, an average for those years will be used for 2006. Data were not available for any years for Brown, Crawford, Floyd, Ohio, and Switzerland counties.

the average harvested acres from 2000 to 2006 for each county. Thus, historical cropping patterns are assumed to be followed into the future. Yields are calculated for 2008 and 2010 using the trend function in Excel such that when calculating county level yield increases, the average state level change is the average annual yield increase from1960 through 2006. Total production is calculated by multiplying the estimated harvested acres by the estimated yield for each respective year and county.

Corn demand at the county level includes four types of utilization. They are 1) livestock consumption, 2) food processing plants, 3) ethanol plants, 4) and country elevators. First, livestock numbers by county for each species are obtained from the USDA in the 2002 Census of Agriculture (US Department of Agriculture 2002). Species included in livestock numbers are cattle on feed, dairy cows, beef cows, other cattle, breeding swine, market swine, layers, pullets, broilers, turkeys, and ducks. Specific definitions for each species are provided in Table 3.1. The USDA withholds reporting livestock production data for some counties to avoid disclosing data for individual farms. The process of allocating livestock within counties with no data is discussed later.

Table 3.1: Definitions of Livestock Species

Specie	Definition
Beef Cows	Breeding cows for beef production
Breeding Swine	Swine produced for breeding purposes
Broilers	Chicks produced for market and meat consumption
Cattle on Feed	Cattle and calves being fed a grain or other concentrate ration for slaughter market that will produce a carcass that will grade select or better
Dairy Cows	Breeding cows for milk and dairy production
Ducks	All ducks produced for slaughter or breeding
Layers	Layer hens in molt and other layers and pullets of 20 weeks old
Market Swine	Swine produced for market
Other Cattle	Includes all heifers, heifer calves, steers, steer calves, bulls, and bull calves
Pullets	Chicks for layer hen replacement younger than 20 weeks old
Turkeys	All turkeys produced for slaughter or breeding

Source: National Agriculture Statistic Service (2007)

The second category of corn utilization is food processing which includes dry milling, wet milling, and grind milling plants. The location and annual corn demanded for seven food processing plants in Indiana is included in the model (Table 3.2). The capacity and location of each plant was obtained from the Grain and Milling Annual publication (Milling and Baking News 2008). Data from this source are as of September 2007.

Table 3.2: Location and Annual Utilization of Corn by Food Processing Plants in Indiana, 2007

City[1]	County	Bu/Corn/Year
Lafayette	Tippecanoe	92,125,000
Hammond	Lake	67,000,000
Indianapolis	Marion	33,835,000
Daviess	Washington	32,160,000
Evansville	Vanderburgh	8,375,000
Marion	Grant	4,020,000
Rochester	Fulton	4,020,000

[1]Lafayette, Indianapolis, and Evansville have more than one plant. Corn required is total for all plants

(Source: Milling and Baking News 2008)

Ethanol is a third source of corn consumption. Location and capacities of each plant for the three time periods are needed. For 2006 and 2008 ethanol plants that were in production as of January 1 of each respective year are included in the model (Table 3.3). There are five sources that report current denatured ethanol capacity as well as construction capacities:

1. Center for Agriculture and Rural Development (CARD) from Iowa State University,
2. Renewable Fuels Association (RFA),
3. Ethanol Producer Magazine,
4. The American Coalition for Ethanol, and
5. Indiana State Department of Agriculture (ISDA).

For production in 2008, all sources agree on the location of six plants but have minor differences among capacities. This study will use current plant location and capacities reported by ISDA. For plants under construction, all locations are reported by four of the five sources with minor differences among capacities. One plant location, Mt. Vernon, is reported by only three sources with large discrepancies in capacity. A September 24, 2007 press release by Aventine Renewable Energy, the company with ownership of the plant, reported that construction of a 226 MGY plant has commenced (Aventine 2007). Because the ISDA works close with planning ethanol construction and their reports are consistent with other sources including the press release, plants reported by the ISDA under construction as of January 1, 2008 are assumed to be producing ethanol in 2010 (Table 3.3).

Table 3.3: Indiana Ethanol Plants in Production and under Construction, 2008

2008 Production Capacity (Denatured)		
City	County	Capacity (MGY)
Clymers	Cass	110
Linden	Montgomery	100
Marion	Grant	40
Portland	Jay	65
Rensselaer	Jasper	40
South Bend[1]	St. Joseph	100
TOTAL		455
Expansion/Construction Plans		
City	County	Capacity (MGY)
Alexandria	Madison	60
Bluffton	Wells	100
Cloverdale	Putnam	60
Harrisville	Randolph	100
Mt. Vernon	Posey	220
North Manchester	Wabash	65
TOTAL Expansion		605
TOTAL PRODUCTION AND EXPANSION		1060

[1]Only the South Bend plant was in production in 2006

(Source: ISDA 2008)

Data for DDGS production are also needed for the model. As a co-product of ethanol production, it is assumed that ethanol plants for each respective year also produce DDGS at full capacity.

Soybean demand at the county level is also required which principally is used by soybean crushing facilities. The location and annual soybean demand for seven crushing facilities are included in the model (Table 3.4). The capacity and location of each plant in 2007 was obtained from the Grain and Milling Annual publication (Milling and Baking News 2008). The facility located in Claypool is a biodiesel plant. However, the initial process of biodiesel production begins with crushing. Therefore, this facility is listed as a crushing facility.

Table 3.4: Location and Capacity of Soybean Crushing Plants

City	County	Bu/Soybeans/Year
Morristown	Shelby	57,750,000
Claypool[1]	Kosciusko	50,000,000
Decatur	Adams	41,580,000
Frankfort	Clinton	27,286,875
Mt. Vernon	Posey	22,435,875
Lafayette	Tippecanoe	19,404,000
Seymour	Jackson	9,702,000
TOTAL		228,158,750

[1]Claypool plant started production fall 2007 and is included in only 2008 and 2010 models.

Source: Milling and Baking News (2008)

Finally, any grain remaining after Indiana demands by livestock, food processors, ethanol plants, and crushers is assumed to be shipped out of state via local country elevators. A partial list of country elevators is found in the Milling and Baking News (2008). Elevators were classified as unit train loaders, a combination rail and truck shipper, or truck houses on the basis of loadout capacity. A unit train elevator had a loadout capacity of at least 35,000 bushels per hour. In Indiana, 81.8 percent of the grain shipped from the state moves by rail (Bureau of Transportation

Statistics 2004). For counties with unit train elevators, 98 percent of the grain was assumed to be shipped by rail. Counties with only truck houses were largely concentrated near the Ohio River, and typically shipped less than two million bushels from the county on an annual basis. The rest of the counties were designated as a rail/truck split. In these counties, the Goal Seek function in Excel was used to arrive at a statewide rail share of 81.8 percent. Appendix A includes designations for each county.

Ethanol demand is also needed for the model. The primary demand point for ethanol is gasoline blending terminals where ethanol is blended with gasoline. The location and capacities of blending terminals are obtained from a 2002 report for the US Department of Energy (Reynolds 2002).

DDGS demand for the state of Indiana is also required. When DDGS is available, it is assumed that it is incorporated into all livestock feed rations at maximum inclusion rates (Table 3.5). To quantify DDGS demand, inclusion rates for all livestock species are obtained (Dhuyvetter, Kastens, and Boland 2005).

Table 3.5: DDGS Inclusion Rate by Specie

Specie	Daily intake of DDGS (lbs)	Days fed per year	Lbs of DDGS per animal per year
Beef Cows	7.22	90	649.80
Breeding Swine	1.21	310	375.10
Broilers	0.02	56	1.16
Cattle on Feed	5.56	365	2,029.40
Dairy Cows	4.17	365	1,522.05
Layers	0.03	365	11.86
Market Swine	0.47	365	171.55
Other Cattle	2.78	135	375.30
Pullets	0.01	365	3.61
Turkeys	0.04	151	6.36

Source: Dhuyvetter et al. (2005)

Because the model includes linear programming models to allocate commodities among counties in Indiana, distances between each county are needed. Distances between counties are estimated using the linear programming model GAMS such that straight line distances between every county seat combination are calculated (Ballou, 2005). Additionally, distances between ethanol plants and gasoline blending terminals are obtained using Google Maps.

3.2 Assumptions

This section focuses on assumptions that must be made for the model. Assumptions are made for grain production, livestock demand for corn, food processing plants, ethanol plants, soybean processing plants, and country elevators.

Crop production data are available for 2006 and forecasted for 2008 and 2010. The forecast assumes historical cropping patterns for corn and soybeans continue through 2010.

Estimating livestock demand for corn requires two assumptions. First, livestock in Indiana are assumed to be fed local corn from within the county they are produced. Second, livestock production in the United States has been in a steady state. Thus, Indiana livestock production numbers in the 2002 census are assumed constant through 2010. Corn consumption rates by species are available and presented in Table 3.6.

Table 3.6: Assumed Corn Consumption Rate by Specie

Specie	Lbs/Corn/Year[1]	Bu./Corn/Year
Beef Cows	448.00	8.00
Breeding Swine	1,600.00	28.57
Broilers	6.33	0.11
Cattle on Feed	6,152.00	109.85
Dairy Cows	4,368.00	78.00
Layers	56.00	1.00
Market Hogs	1,820.00	32.50
Other Cattle	862.90	15.41
Pullets	56.00	1.00
Turkeys	44.02	0.79

[1]Other cattle and breeding swine rates from Dhuyvetter et al. (2005), all other rates from Hurt (2007).

In 2006, only one ethanol plant was producing in Indiana. Therefore, DDGS supply was limited to livestock in close proximity to that plant, near South Bend. However, when additional ethanol plants come online in 2008 and 2010, it is assumed that DDGS is fed to all livestock in Indiana. DDGS is incorporated into livestock diets at the inclusion rates in Table 3.5. When DDGS is fed, it is assumed that corn consumption rates from Table 3.6 decrease by 11 percent for swine and poultry and 18 percent for all types of cattle (Iowa Civic Analysis Network 2007).

Corn flows to livestock demand are assumed to take place 365 days per year via 500 bushel capacity trucks. It is also assumed that local livestock corn demand is fulfilled prior to food processing or ethanol demand.

Food processing, ethanol plants, and soybean crushing plants in Indiana typically consume more grain than is available in the local county. For all three utilizations, available grain from the home county is first used after feeding corn to local livestock. Linear programming models are used to allocate grain production among these consumption points, minimizing the cost to transport grain.

Food processing plants in production in 2006 are assumed to produce at the same rate through 2010. It is also assumed that all plants run at full capacity for 350 days per year. Furthermore, it is assumed that corn is transported to these plants in semi-trailers with a capacity of 920 bushels.

Ethanol plants are assumed to operate at full capacity for 354 days per year and that corn is transported in 920 bushel semi-trailers (Denicoff, 2007). It is also assumed that one bushel of corn produces 2.79 gallons of denatured ethanol and 18 pounds of DDGS (Mosier and Klein 2006).

Soybean crushing facilities in Indiana are assumed to operate at full capacity for 350 days per year and that soybeans are supplied via 920 bushel semi-trailers. It is also assumed that the same facilities will be operating from 2006 through 2010, except for the Claypool biodiesel plant which starts production in the 2008 model.

After corn and soybean demands are fulfilled in each county, it is assumed that all remaining grain is first transported to local country elevators where it can be stored and eventually shipped out of Indiana. Because of the seasonal nature of the elevator industry, it is assumed that elevators operate 250 days per year and that grain is received by 600 bushel trucks, which represent a combination of 920 bushel semi-trailers and 500 bushel farm trucks. The mix is approximately 24 percent semi-trailers and 76 percent farm trucks.

Additional assumptions are also made to model outbound ethanol and DDGS flows. The USDA reported state level demands for E-10 ethanol (Denicoff 2007) for 20 locations and capacities of terminal blenders were reported in 2002 (Reynolds 2002). It is assumed that the ethanol markets west of Indiana were satisfied with ethanol from Iowa and Illinois. In addition, it is assumed that demands in Kentucky, Michigan, and Ohio are those remaining after consuming locally produced ethanol. Thus, it is assumed that 760 MGY of ethanol demand can be served from Indiana ethanol plants as a truck market (Table 3.7). It is assumed that Indiana ethanol first satisfies the truck market and the remaining ethanol is railed from the region. It is assumed that ethanol transported within the truck market is done so via trucks with 8,000 gallon capacities. Ethanol railed out of the region is done so via rail cars with a capacity of 29,400 gallons (Denicoff 2007).

It is assumed that DDGS demand in Indiana is fulfilled via truck with a capacity of 25 tons. Remaining DDGS after Indiana demand is fulfilled is transported out of the state via rail cars with a capacity of 100 tons (Denicoff 2007).

Table 3.7: Assumed Location and Annual Demands for Truck Markets for Indiana Ethanol Producers, 2006-2010

Location	Annual Demand for Ethanol for Truck Based Market (MGY)	Distance in miles from nearest Indiana Ethanol Plant (2010)
Evansville, IN	40	50 (Posey)
Huntington, IN	20	47 (Wabash)
Indianapolis, IN	155	80 (Madison)
South Bend, IN	75	12 (St. Joseph)
Brookston, IN	10	67 (Jasper)
Muncie, IN	20	46 (Madison)
Lexington, KY	30	241 (Randolph)
Louisville, KY	200	192 (Putnam)
Detroit, MI	160	242 (Wells)
Marshall, MI	15	145 (St. Joseph)
Jackson, MI	35	179 (St. Joseph)
TOTAL	760	

Source: (Reynolds 2002)

3.3 Model Development

The goal of the model is to compare and evaluate the effects that ethanol expansion will have on transportation requirements. The model is developed for three time periods such that changes in transportation requirements can be determined before, during, and after ethanol expansion takes place in Indiana. The only changes between time periods are adjustments to crop production, the addition of ethanol plants, the addition of a biodiesel plant, and changes in livestock consumption when DDGS is fed. To capture changes in transportation requirements among the three time periods, the model estimates total truck loads, miles driven by each truck (VTM), and rail car loads at a county level for commodity flows of corn, soybeans, ethanol, and DDGS. The change in truck loads, VTM, and rail loads among the three periods will capture the effects that biofuel expansion will have on transportation requirements.

This section discusses model development in detail. The model consists of a sequence of 12 steps. The steps are:

1. Estimate county grain production for all three time periods.
2. Livestock allocation and feed demand among all Indiana counties.
3. Estimate total truck loads and VTM required to supply livestock with corn.
4. Linear programming model to allocate remaining corn to food processing and ethanol plants.
5. Estimate total truck loads and miles required to independently supply food processing and ethanol plants with corn.
6. Estimate total truck loads and miles to allocate remaining corn to country elevators.
7. Linear programming model to allocate soybeans to soybean crushing facilities.
8. Estimate total truck loads and miles required to supply crushing facilities with soybeans.
9. Estimate total truck loads and miles to allocate remaining soybeans to country elevators.
10. Linear programming model to allocate ethanol within the truck market area and estimate total truck loads and miles to supply ethanol to blending terminals.
11. Linear programming model to allocate DDGS to livestock within Indiana and estimate total truck loads and miles to supply DDGS to Indiana livestock.
12. Allocate grain from local country elevators to out-of-state demands via truck and rail.

STEP 1: Estimate County Grain Production

Grain production is available from the National Agricultural Statistics Service (NASS) for 2006 and is estimated for 2008 and 2010 (US Department of Agriculture 2007b). To estimate grain production for 2008 and 2010, harvested acres are projected first. Harvested acres for 2008 and 2010 are the average harvested acres from 2000 to 2006 for each county. Thus, historical cropping patterns are assumed to be followed into the future. County level corn yields are calculated for 2008 and 2010 using the trend function in Excel. The state average yield increase for Indiana from 1960-2006 is 1.65 bushels per acre. However, state level yield increases from 2000 through 2006 are 2.71 bushels per acre. To accurately estimate county level yield for

2008 and 2010, the trend function in Excel is used with base years of 2000 through 2006 but with a maximum annual yield increase constraint of 2.59 bushels. This county level maximum constraint allows the state level average yield increase per year to be 1.65 bushels per acre, or the state level yield increase since 1960. Because soybean yields are steadier over time, they are calculated for 2008 and 2010 using the trend function in Excel with base years of 2000 through 2006.Total production is calculated by multiplying the estimated harvested acres by the estimated yield for each respective year and county.

STEP 2: Estimate Livestock Numbers

The market value of production for Indiana agriculture was $4.8 billion in 2002, of which $1.7 billion was from livestock (US Department of Agriculture 2004). Historically, around 20 percent of the corn has been fed to local animals rather than being shipped to other uses. Thus, obtaining estimates of animal numbers at the county level is important to modeling grain flows.

In most cases, but not all, the Census of Agriculture reports the number of animals by county. The main reason that data are not reported is to avoid disclosure. However, by combining data for the inventory of animals, the value, and number of animals sold, one can obtain a reasonable estimate for missing values. The goal of this step is to first report available data, and then explain the process to estimate missing values.

Total animal sales are available for all counties except Marion and Warren. Given the metropolitan nature of Marion County, it is likely that most of the $26.3 million can be assigned to Warren County. Dairy, cattle, hogs, and poultry account for 18.6 percent, 18.1 percent, 35.4 percent, 25.4 percent of total sales, respectively, or 97.5 percent of all animal sales for the state. The remaining categories include: sheep, goats, and their products; horses, ponies, mules, burros, and donkeys; aquaculture; and other animals. Except for ducks, these categories are ignored for this this analysis.

For dairy, $230.6 of the $333.3 million in sales is reported, with 27 counties reporting no sales (Table 3.8). For cattle, $301.8 of the the $324.1 million in sales is reported, with 14 missing observations, while hogs have $564.4 of $633.1 million in sales reported (14 missing counties), and poultry have $303.8 of $451.2 million (with 39 missing counties). Reported sales data are missing for 30.8 percent, 6.9 percent, 10.9 percent, and 33.3 percent of for dairy, cattle, hogs, and poultry, respectively.

The Census of Agriculture also has data on inventory numbers for all cattle, dairy, and hogs. Data for poultry are further subdivided into layers, pullets, broilers, turkeys, and ducks. Inventory numbers are readily available for dairy, cattle, and hogs, with 10.0 percent, 0.0 percent, and 2.6 percent respectively of the inventory not reported at the county level, and only 15 counties with missing observations (Table 3.9). In contrast, for poultry, 76.8% and 65.1% of the layers and pullets are not reported at the county level, and as many as 38 counties have missing values for poultry.

Table 3.8: 2002 Census Sales for Indiana, by Animal Type, by County[1]

Type of Animal	Indiana Census Total ($000)	Percent of State Sales Total	Total Sales Reported at County Level ($000)	Percent of State Total Sales Missing	Number of Counties with Missing Observation
Dairy Sales	333,339	18.6%	230,606	30.8%	27
Cattle Sales	324,054	18.1%	301,794	6.9%	14
Hog Sales	633,112	35.4%	564,393	10.9%	14
Poultry Sales	455,153	25.4%	303,811	33.3%	39
Total Animal Sales	1,790,411	97.5%	1,764,101	1.5%	2

[1]For county level data, see Appendix B

Source: US Department of Agriculture (2002)

Table 3.9: 2002 Census Inventory for Indiana, by Animal Type, by County[1]

Type of Animal	Indiana Census Total Number of Animals	Total Number of Animals Reported at County Level)	Percent of State Total Inventory Missing	Number of Counties with Missing Observation
Dairy Inventory	144,792	130,318	10.0%	9
Cattle Inventory	862,074	862,074	0.0%	0
Hog Inventory	3,478,570	3,386,611	2.6%	6
Layers	21,952,110	5,103,365	76.8%	20
Pullets	5,764,843	2,009,860	65.1%	38
Broilers	3,823,936	3,547,140	7.2%	30
Turkeys	3,848,054	3,489,830	9.3%	38
Ducks	1,143,160	1,121,741	1.9%	16

[1]For county level data, see Appendix C

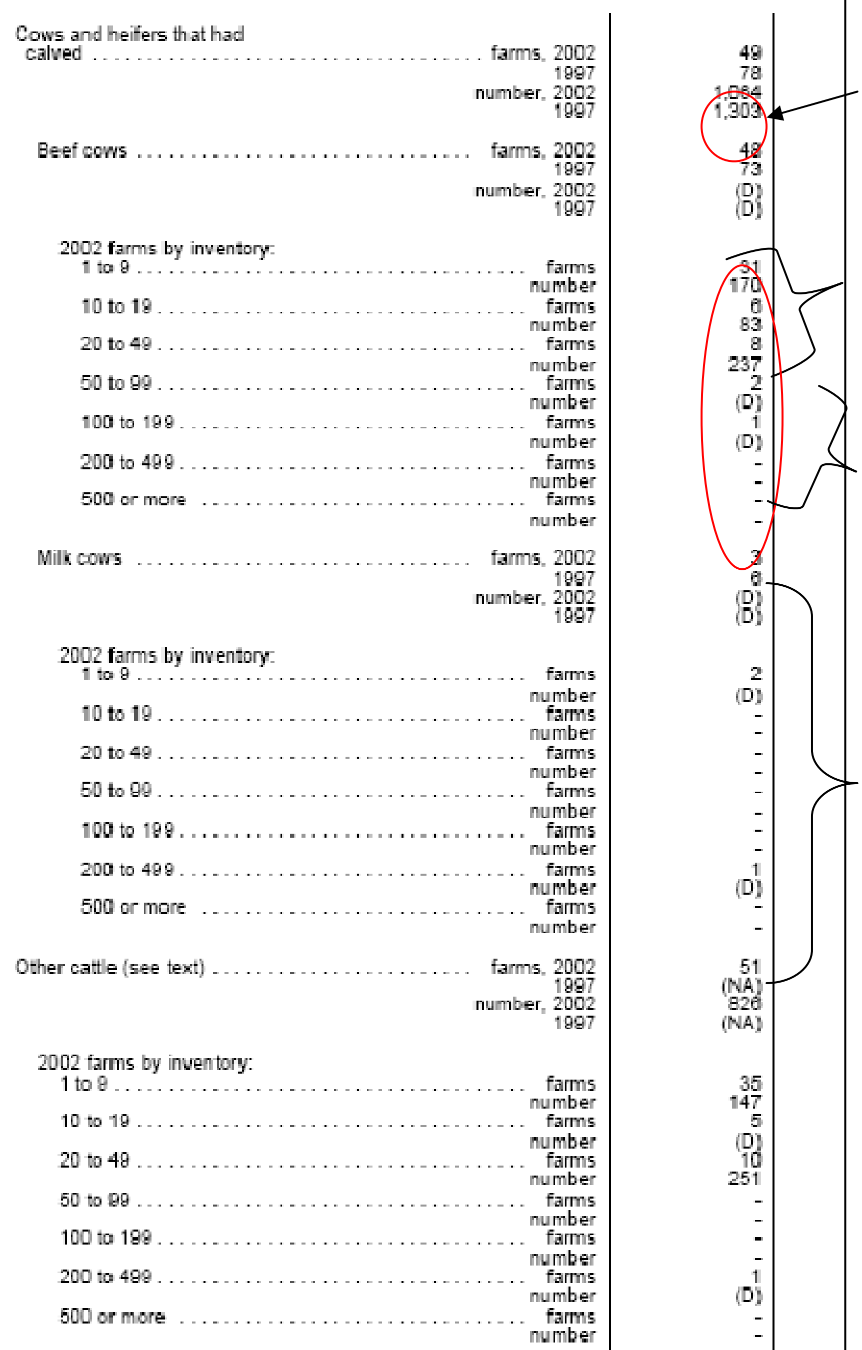
Source: US Department of Agriculture (2002)

The process to estimate missing animal numbers starts by reconciling the number and sales of cattle and dairy. The process is then repeated for hogs, and finally for poultry. Appendices B and C are then updated and used to generate county level feed demands for corn and DDGS.

Tables 3.8 and 3.9 report values for all cattle and dairy. All cattle includes dairy cattle, as well as beef cattle, and other cattle. Thus,

(3.1) Total Cattle= Other Cattle + Beef Cows + Milk Cows

Data for Total Cattle and Other Cattle are reported for each county. However, data are missing for 9 counties for beef cows and milk cows (namely, Brown, Floyd, Miami, Newton, Pike, Scott, Starke, Tipton, and Warren) (see Appendix D). Table 11 of the Census of Agriculture reports data by size of herd for beef and milk cows. For some size classifications, the number of head are reported at the county level. Figure 3.1 shows the available data for Brown County from the Census of Agriculture, with an explanation to the right. The process explained in Figure 3.1 was applied to each county with missing data for beef and milk cows (Table 3.10). These adjustments mean that inventory levels for all cattle are adjusted and consistent with state totals.



Cows and heifers that had calved	farms, 2002	49
	1997	78
	number, 2002	1,064
	1997	1,303
Beef cows	farms, 2002	48
	1997	73
	number, 2002	(D)
	1997	(D)
2002 farms by inventory:		
1 to 9	farms	31
	number	170
10 to 19	farms	6
	number	83
20 to 49	farms	8
	number	237
50 to 99	farms	2
	number	(D)
100 to 199	farms	1
	number	(D)
200 to 499	farms	-
	number	-
500 or more	farms	-
	number	-
Milk cows	farms, 2002	3
	1997	6
	number, 2002	(D)
	1997	(D)
2002 farms by inventory:		
1 to 9	farms	2
	number	(D)
10 to 19	farms	-
	number	-
20 to 49	farms	-
	number	-
50 to 99	farms	-
	number	-
100 to 199	farms	-
	number	-
200 to 499	farms	1
	number	(D)
500 or more	farms	-
	number	-
Other cattle (see text)	farms, 2002	51
	1997	(NA)
	number, 2002	826
	1997	(NA)
2002 farms by inventory:		
1 to 9	farms	35
	number	147
10 to 19	farms	5
	number	(D)
20 to 49	farms	10
	number	251
50 to 99	farms	-
	number	-
100 to 199	farms	-
	number	-
200 to 499	farms	1
	number	(D)
500 or more	farms	-
	number	-

Figure 3.1: Example of Table 11 for Brown County from the Census of Agriculture

To start, the Table 11 reports that 1,064 cows and heifers had calved. However, this numbers is not allocated between beef or milk cows.

48 farms in Brown County raised beef cows.

Number of head raised is available for 45 of the 48 farms. These 45 farms raised 170 + 83 + 237 beef cows for a total of 490 beef cows reported.

We also know that 2 farms raised between 50 to 99 beef cows, while the last farm raised between 100 to 199 beef cows. The median value of 75 and 150 is applied for the two ranges, adding another 300 cows, or a total of 790 beef cows.

In most cases, there are only a handful of dairies. Thus, the remainder is assigned to dairies, or 1064 – 790 = 274 dairy cows. Note that two of the three dairies have 1 to 9 cows, while the other dairy is from 200 to 499 head. Thus, the total number of milk cows is consistent with farms by inventory.

Table 3.10: Adjustments to Beef and Dairy Herds, by County

Item	Brown	Floyd	Miami	Newton	Pike	Scott	Starke	Tipton	Warren
Total Beef and Dairy Cows	1,064	1,525	3,648	13,478	1,614	2,018	528	299	1,659
Number of Beef Farms	48	118	120	60	62	118	33	16	77
Beef Farms Reporting	45	114	116	48	52	110	31	16	66
Missing Beef Farms	3	4	4	12	10	8	2	0	11
Reported Beef by Size	490	1237	1246	1005	1411	1797	317	185	1517
Median Value for Beef	300	251	402	555	128	206	136	39	137
Adjustment to Beef Herd	790	1,488	1,648	1,560	1,539	2,003	453	224	1,654
Number of Dairy Farms	3	1	18	4	1	1	1	1	1
Dairy Farms Reporting	0	0	12	3	0	0	0	0	0
Reported Dairy by Size	0	0	1010	6	0	0	0	0	0
Missing Dairy Farms	3	1	6	1	1	1	1	1	1
Median Value for Dairy	274	37	990	11,912	75	15	75	75	5
Adjustment to Dairy Herd	274	37	2,000	11,918	75	15	75	75	5

The inventory numbers were then used to update Appendix D. The state average value of cattle was $537.73 per head. The average for the counties reporting both inventory and sales data was $534.42 per head. Thus, the 37,519 head that were not valued, were costed at $593.30, to reach the state total this amount was used to determine sales for the 14 missing counties. For dairy, value per milk cow was $2,198.74 for reported counties, and $2,574.05 for missing counties, to arrive at a total of $2,302.19 per head statewide.

A similar process was then applied for hogs. In this case, 2.6 percent of the state's 3,478,570 hogs from 6 counties were missing values (Table 3.8). Hogs are divided into two types of animals, breeding and market, with different nutritional requirements and diets. Statewide, 11.5 percent of the missing hogs are breeding swine, while the remainder is market swine. At the breeding and market swine level, data are missing for 14 counties. However, total swine numbers are available for 9 of the missing 14 counties (Table 3.11). This accounts for 129,803 of the missing hogs, leaving 90,771 hogs unaccounted for in Marion, Ohio, Switzerland, Vermillion, and Warren Counties.

The number of farms raising hogs is available by farm size in these 5 counties. Median values for the ranges are used to estimate the total number of hogs for all farms, except for farms with more than 1,000 hogs. This totals 2,001 hogs, leaving 88,770 hogs to be divided among 4 large hog farms in the adjacent counties of Vermillion and Warren. Appendices B and C are then updated to reflect the adjusted hog numbers.

Table 3.11: Adjustments to Breeding and Market Swine, by County

Item	Breeding	Market	Total
State Total	336,240	3,142,330	3,478,570
Reported	310,770	2,947,226	3,257,996
Missing Hogs	25,470	195,104	220,574
% by Class	11.5%	88.5%	
County with Total Reported, but not allocated			
Brown	8	64	72
Floyd	8	62	70
Greene	6,622	50,731	57,353
Jefferson	123	942	1,065
Lake	319	2,448	2,767
Monroe	2	21	23
Newton	6,262	47,976	54,238
Vanderburgh	386	2,960	3,346
Vigo	1,255	9,614	10,869
Adjusted	14,985	114,818	129,803
Missing Hogs	10,485	80,286	90,771
County allocated on basis of farm size			
Marion	9	76	85
Ohio	9	76	85
Switzerland	91	704	795
Vermillion	5,242	40,160	45,402
Warren	5,127	39,277	44,404

After adjusting county level livestock sales for cattle, dairy, and hogs, we turn to poultry. Numbers are estimated for layers, pullets, broilers, turkeys, and ducks. For layers, only 5,103,365 of 21,952,110 birds are reported at the county level (Table 3.8), with 20 counties missing data. However, data report the number of farms raising layers at the county level, on basis of farm size in terms of number of layers. For example, no data are reported for layers in Jasper County (see Figure 3.2).

Jasper county has 21 farms with 1 to 49 birds, 2 farms with 50 to 99 birds, and 1 farm with more than 100,000 birds. Layers are allocated by farm size for the 20 counties with missing data. Since there is no median for the last category, (over 100,000 birds), the remainder of birds in the state (16,623,439) is divided among the 16 mega-farms, or slightly over 1 million birds per farm. This number should be viewed with considerable caution, yet is the best alternative given the lack of data. Counties with mega-layer farms are Clinton (2), Jackson, Jasper, Jennings, Kosciusko (2), Martin, Newton, Orange, Pulaski, St. Joseph, Tipton, Wabash, Wells, and White.

Table 3.12: Reconciliaton of Layers

Item	Number of birds		
State Total Layers			21,952,110
Layers Reported at the County Level			5,103,365
Missing Layers Statewide			16,623,439
Size of Farms, by in birds	Number of Farms	Median number of layers per Farm	Estimated number of birds in missing counties
1 to 49	281	25	7,025
50 to 99	33	75	2,475
100 to 399	16	250	4,000
400 to 3,199	1	1,800	1,800
3,200 to 9,999	0	6,600	0
10,000 to 19,999	2	15,000	30,000
20,000 to 49,999	3	35,000	105,000
50,000 to 99,999	1	75,000	75,000
100,000 or more	16		16,623,439

Like layers, data for pullets are not available by farm size and data are missing for many counties (38) and birds, (2,009,860 of a state total of 5,764,843 pullets) (Table 3.8). Given that pullets serve to replenish the stock of layers, it is assumed that the missing layers are found in the same proportion as the allocation of layers.

Table 13. **Poultry - Inventory and Sales: 2002 and 199**

[For meaning of abbreviations and symbols, see introductory text]

Item	Jasper	Jay
INVENTORY		
Any poultry . . . . . farms, 2002	28	62
1997	14	70
Layers 20 weeks old and older . . . . . farms, 2002	24	42
1997	9	47
number, 2002	(D)	2,281,639
1997	(D)	1,780,053
2002 farms by inventory:		
1 to 49	21	25
50 to 99	2	2
100 to 399	-	-
400 to 3,199	-	-
3,200 to 9,999	-	-
10,000 to 19,999	-	3
20,000 to 49,999	-	1
50,000 to 99,999	-	3
100,000 or more	1	8

Data from Jasper and Jay explain how the missing number of layers was reconciled.

Figure 3.2: Example of Table 13 from Census of Agriculture

STEP 3: Calculate Distance to Truck Corn to Livestock at the County Level

Once livestock feed demand is known for all counties, corn is allocated to fulfill livestock corn demand. Because it is assumed that livestock corn demand is fulfilled first, corn is simply allocated from within the county to fulfill livestock demand. Total daily truckloads are then calculated as:

$$(3.2)\quad \text{Total Daily Truck Loads}_{\text{j}} = \frac{\left(\dfrac{\text{Annual Grain Demanded}_{\text{j}}}{\text{Days of Operation}_{\text{u}}}\right)}{\text{Truck Capacity}_{\text{u}}}$$

where j denotes the type of grain being used and u denotes the type of utilization of the grain. For example, assume that a county has an annual demand of 2,000,000 bushels to feed livestock. Livestock are fed each day, meaning days of operation is 365. If truck capacity is 500 bushels, the 5,479 bushels fed per day require 11 trucks.

Also required in the model is density of grain in terms of bushels per square mile within the county, or:

$$(3.3)\quad \text{Crop Density}_{\text{i,j}} = \left(\frac{\text{Crop Acres}_{\text{i,j}}}{\text{Total Acres}_{\text{i}}}\right) \times \text{Yield}_{\text{i,j}} \times 640$$

Crop acres are defined as total harvested acres and total acres are defined as total land area in county i. Yield is in terms of bushels per acre. By multiplying by 640 (the number of acres per square mile), crop density is calculated on a density per square mile basis. Equation 3.3 is calculated separately for corn and soybeans. Continuing the example, assume a county has 300,000 total acres and 73,242 acres of corn with an average yield of 160 bushels/acre. Crop Density would be 25,000 bushels/section.

Distance traveled by each truck is based on radii extending from a demand point or:

(3.4)

$$\text{Distance Traveled}_{i,j,u} = \sum_{j=1}^{J}\left(\sqrt{\frac{\text{Truck Number}_j \times \text{Truck Capacity}_u}{\frac{\pi \times \times \text{Crop Desity}_{i,j}}{\text{Days of Operation}_u}}}\right) \times \text{Circuity Factor}$$

Equation 3.4 is solved iteratively for each truck load$_j$ required to meet demand such that a summation of the distances traveled by each truck provides total miles driven by all trucks. For example, assume that a county needs 11 trucks to meet the corn utilization for feeding livestock. Thus, truck number will be 1, 2, 3, etc, or in this case though 11, meaning eleven 500 bushel trucks must be filled to satisfy demand. The distance of truck 1 is the square root of 1 times truck capacity of 500 bushels divided by the denominator in the square root term of equation 3.4. For trucks 2, 3, 4, etc. the capacity is multiplied by 2, 3, and 4 respectively. As a result each additional truck must travel a further distance to meet the utilization demand. This method of calculation provides output for the number of truckloads required to meet a particular use (livestock, food processing, etc.) and the distance traveled by each truck. Dividing total distance traveled by Total Daily Loads gives average one-way LOH or trip distance. Thus, the total distance traveled is a function of the number of trucks, truck capacity, and grain density. Because distances traveled are calculated as straight line distances, each distance is multiplied by a circuity factory of 1.21 to arrive at a better estimate of distance (Ballou 2005).

STEP 4: Allocation of Corn to Food Processing and Ethanol Plants

After livestock demand for corn is fulfilled at the county level, the remaining corn is allocated to food processing and ethanol plants. Because of the large quantity of corn demanded by both food processing and ethanol plants, the draw area for each plant will likely extend into adjacent counties. Given competing demands for corn, a cost minimizing transportation linear programming model is used to allocate corn. Before this can be done, truck transportation costs must be estimated. A three-step process was used to estimate per mile truck costs. First, the Grain Truck Transportation Cost Calculator, is used to generate per mile costs (Edwards 2002). The model requires that the user apply assumptions about the purchase price, salvage value and estimated useful life of a semi and grain hopper, costs of tires, miles driven per year, price of fuel, fuel efficiency, and driver wage rates. Estimates for semi-tractor and hopper costs were provided by Dooley (2008).

Second, annual miles were estimated by assuming that a trucking firm will haul grain 250 days per year, working 12 hour shifts per day. Given a distance traveled and an average speed, time can be calculated per trip. An assumed time to load and unload is 150 minutes per trip (Berruto and Maier 2001). Given 720 minutes per day, the number of loads that can be hauled per day are then calculated. Annual miles are then the product of trips per day and miles per trip. Average total costs (ATC) were generated for round trip distances from 5 to 300 miles.

Third, because it is a non-linear relationship, the natural log of ATC was then regressed against the natural log of miles, giving the following estimate of ATC:

$$(3.5)\ \ \mathrm{Ln}(\mathrm{ATC}) = \underset{(21.071)}{1.7435} - \underset{(-15.0069)}{.25674 \times \mathrm{Ln}(\text{miles per trip})} \qquad R^2 = .7917$$

where the values in parentheses are t-statistics. Equation 3.5 was then used to generate trucking costs for each possible movement.

The objective of the linear programming model is to minimize cost when allocating corn to all food processing and ethanol plants. The LP equations are:

(3.6) OBJECTIVE: MIN ((G,U), D(G,U)*X(G,U))

CONSTRAINTS: SUM (J, X(G,U)) < A(G)

SUM (I, X(G,U)) > B(U)

where G are grain production counties, U are grain consumption counties, D(G,U) is the cost to ship grain between a production county and consumption county, X(G,U) is bushels shipped between a grain production county and grain consumption county, A(G) is bushels of grain produced by county G, and B(U) is bushels of grain demanded by county U. The output of this model provides bushels of corn allocated from a production county to a county with an ethanol or food processing plant.

STEP 5: Calculate Distance to Truck Corn to Food Processing and Ethanol Plants at the County Level

Equations 3.2, 3.3, and 3.4 are used to calculate daily inbound trucks VTM for counties with food processing and ethanol plants. Food processing plants are found in seven counties (Table 3.2). Ethanol demands vary from one county in 2006 to six in 2008 to twelve in 2010 (Table 3.3). Compared to livestock demands, food and ethanol demands are much larger.

STEP 6: Calculate Distance to Haul Corn to Country Grain Elevators

Any corn remaining after allocation to livestock, food processing, and ethanol plants is transported to local country elevators. Equations 3.2, 3.3, and 3.4 are used to determine daily truckloads required and VTM.

STEP 7: Allocation of Soybeans to Crushing Plants

Soybeans are allocated to soybean crushing facilities like corn to food processing and ethanol plants in step 4. Because of the large quantity of soybeans demanded by soybean crushing facilities, the draw area of each facility extends into adjacent counties. Thus, a transportation linear programming model is once again used to allocate soybeans to crushing facilities (equation 3.6).

STEP 8: Calculate Distance to Truck Beans to Crushers at the County Level

Equations 3.2, 3.3, and 3.4 are used to estimate daily inbound truck loads of beans required for each crushing facility and VTM similar to equations used in step 5 for corn to food processing and ethanol plants. It is assumed that trucks have a capacity of 920 bushels and that plants operate 350 days per year. A normal soybean density is around 8,000 bushels per section which is much lower compared to a normal corn density of 25,000 bushels per section. This can be attributed to soybeans having lower yields, around 47 bushels per acre. Because density and yield are both lower compared to corn, it can be expected that trucks shipping beans to crushing facilities will have to travel further compared to trucks transporting corn to food processing and ethanol plants.

STEP 9: Calculate Distance to Haul Soybeans to Country Grain Elevators

Soybeans remaining after demand for all crushing facilities are met are transported to country elevators similar to corn shipments to country elevators in step

6. Equations 3.2, 3.3, and 3.4 are used to determine daily truckloads required and distance each truck travels.

STEP 10: Allocation of Indiana Ethanol to Terminal

Outbound ethanol is allocated to truck markets, which are defined as gasoline blending terminals within 300 miles of Indiana. This includes 11 gasoline blending terminals in Indiana, Michigan, and Kentucky (Table 3.7). Distances between each ethanol plant and each truck market location were obtained from Google Maps. A transportation linear programming model was used to allocate ethanol between ethanol plants and truck markets minimizing cost. The LP equations are:

(3.7) OBJECTIVE: MIN ((E,T), D(E,T)*X(E,T))

CONSTRAINTS: SUM (T, X(E,T)) < A(E)

SUM (T, X(E,T)) = A(E)

SUM (E, X(E,T)) < B(T)

where E are ethanol production plants, T are blending terminals, D(E,T) is costs to transport ethanol between a plant and blending terminal, X(E,T) is gallons shipped between an ethanol plant and blending terminal, A(E) is gallons of ethanol produced by plant E, and B(T) is gallons of ethanol demanded by blending terminal T.

Output from this model provides gallons of ethanol allocated between ethanol plants and blending terminals. Daily truck loads of ethanol are then calculated by the following equation:

$$\text{(3.8) Total Daily Truck Loads} = \frac{\left(\dfrac{\text{Product From Ethanol Plant}_x}{\text{Days of Operation}} \right)}{\text{Truck Capacity}_y}$$

where x is the type of product produced by an ethanol plant, either ethanol or DDGS, and y denotes truck capacity for either ethanol or DDGS. Ethanol plants are assumed to operate 354 days per year and transport ethanol in trucks with 8,000 gallons of capacity. Daily VTM by each truck are then calculated using the following equation:

(3.9)

$$\text{Daily Truck Miles} = \text{Daily Truck Loads} \times \text{Miles Between Production and Demand Point}$$

Ethanol remaining after the truck market is supplied is shipped out of state via rail. Daily rail loads are calculated using the following equation assuming a rail tankcar capacity of 29,400 gallons:

$$\text{(3.10)}\quad \text{Daily Rail Loads} = \frac{\left(\dfrac{\text{Remaining Product}_x}{\text{Rail Capacity}_z}\right)}{\text{Days of Operation}}$$

where z denotes capacity of rail carloads for either ethanol or DDGS.

STEP 11: Allocation of Indiana DDGS to Instate and Out-of-State Feeders

Outbound DDGS is allocated to livestock in Indiana via truck. Transportation costs between DDGS production counties and livestock production counties are from step 4. With costs known, a transportation linear programming model is used to allocate DDGS to livestock within Indiana. The equations used in the model are:

(3.11)OBJECTIVE: MIN ((I,J), D(I,J)*X(I,J))

CONSTRAINTS: SUM (J, X(I,J)) < A(I)

SUM (I, X(I,J)) > B(J)

where I are DDGS production counties, J are DDGS consumption counties, D(I,J) is costs to transport DDGS between a production county and consumption county, X(I,J) is tons of DDGS shipped between a DDGS production county and DDGS consumption county, A(I) is tons of DDGS produced by county I, and B(J) is tons of DDGS demanded by county J.

Output from this model provides tons of DDGS allocated from a production county to a demand county. Equation 3.8 and 3.9 are used to calculate truckloads and VTM using output data. DDGS remaining after demand by Indiana livestock is fulfilled is transported out of state by rail using equation 3.9.

STEP 12:

Corn and soybeans stored in country grain elevators after all Indiana demands are met are assumed to be shipped out of state. As mentioned, counties are designated as rail shippers if their elevators ship 95% of their grain by rail, truck elevators if there are no rail elevators, and the remaining counties as a mix between truck and rail with 83.1% of grain being shipped by rail and the remainder by truck (Appendix A). These percentages are multiplied by the bushels of corn and soybeans transported to a country elevator in each county. This provides the annual grain transported by rail and truck on the county level. Total daily truckloads and distance traveled can then be calculated using equation 3.8 and 3.9. It is assumed that grain transported from elevators takes place 250 days per year in 920 bushel trucks. Total daily rail loads can also be calculated using equation 3.8 but rather than a truck capacity of 920 bushels, a rail capacity of 3,500 bushels is used instead.

3.4 Conclusions

The process detailed in steps 1-12 provides estimates of daily truck loads and miles for corn, soybeans, ethanol, and DDGS as well as daily rail loads of ethanol, DDGS, and grain leaving Indiana at the county level. Because this data is reported at the county level, it becomes possible to generate state totals as well as totals for groups of counties. Results of the model are discussed in the next chapter.

To determine changes in transportation requirements between the three time periods, differences in truck loads, miles driven, and rail loads are compared. The difference in these areas between time periods signal what changes in transportation requirements can be expected.

CHAPTER 4: EMPIRICAL RESULTS

The model described in Chapter 3 was built in Excel, using output from four linear programming models providing allocations. Three models were estimated for all 92 counties in Indiana, plus 39 border counties in adjacent states. The three models are a baseline (2006) which can be compared with a short term adjustment (2008) and a long term adjustment (2010). In this chapter, results are reported on a state level.

This chapter will examine the statewide results in detail. A wealth of information is available, including 1) changes in grain production and utilization, 2) inbound truckloads of grain to meet demands for livestock, food processing, ethanol, oilseed crushing, and grain elevators, and 3) outbound shipments of corn, soybeans, DDGS, and ethanol, by truck and rail. Results are first reported at the state level for average one-way LOH, number of one-way loads per day, and daily and annual VTM for the various inbound and outbound movements. Next annual totals are reported, with a focus on the relative contributions of the different inbound and outbound movements. Finally, annual totals are compared for two types of counties, 1) those with construction of biofuel plants by 2010 and 2) the adjacent counties in 2010.

4.1 Statewide Grain Production

Since 2006, higher corn and bean prices, in part due to the growth in biofuels, have led to increased grain production in Indiana. From 2006 to 2008, total corn bushels in Indiana are forecast to increase by 5.3 percent, and are then projected to grow by an additional 2.5 percent from 2008 to 2010 (Table 4.1). Soybean production is forecast to fall by 1.7 percent from 2006 and 2008, but then increases from 2008 to 2010 by 3.1 percent. Total bushels of corn and beans grow from 1.14 to 1.18 billion to 1.21 billion bushels in 2006, 2008, and 2010, respectively. This represents a growth of 3.6 and 2.6 percent between the time periods in available bushels to be moved. Thus, part of the growth in grain transportation in Indiana is simply more production. However, in part this is offset because corn and soybean density also increase over time, meaning that grain production is more concentrated.

Table 4.1: Indiana Grain Production, Yield, and Density, by Year

Grain Production	Model			Percent change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn Production (M bu)	850.8	896.2	918.2	5.3%	2.5%
Soybean Production (M bu)	286.1	281.2	290.0	-1.7%	3.1%
Total bushels (M bu)	1,137	1,177	1,208	3.6%	2.6%
Corn Yield (bu/acre)	145	150	152	3.4%	0.9%
Soybean Yield (bu/acre)	46	47	48	1.0%	3.0%
Corn Density (bu/section)	23,033	24,267	24,857	5.4%	2.4%
Soybean Density (bu/section)	7,823	7,676	7,912	-1.9%	3.1%

Livestock consumption of corn fell from 2006 to 2008 by 7.6 percent, and was then constant from 2008 to 2010 (Table 4.2). The main reason underlying the decline is the replacement of corn by DDGS in livestock feed rations (see Table 2.4). The assumed livestock consumption of DDGS is saturated in Indiana in 2008, thus there is no further reduction from 2008 to 2010. The assumed DDGS feeding rates likely overstate the adoption of DDGS as a substitute for corn. To that extent, the model understates outbound shipments of DDGS from Indiana via rail and overstates available corn. Daily and annual VTM decreased by 13.9 percent between 2006 and 2008. VTM fell more than corn bushels consumed by livestock because corn density increased over time (Table 4.1). The average one-way LOH fell from 5.1 to 4.8 miles per trip. Thus, livestock consumption represents very short one-way hauls.

Table 4.2: Truckloads, VTM, and Average LOH for Livestock Utilization of Corn, by Year

Livestock Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	172.3	159.2	159.2	-7.6%	0.0%
Daily Loads	944	873	873	-7.6%	0.0%
Daily VTM	4,843	4,170	4,123	-13.9%	-1.1%
Average LOH (mi)	5.1	4.8	4.7	-6.8%	-1.1%
Annual Loads	344,533	318,463	318,463	-7.6%	0.0%
Annual VTM	1,767,737	1,522,104	1,504,749	-13.9%	-1.1%

The number of food processing plants remains unchanged over the three time periods and therefore, corn consumption and daily truckloads for food processing also remain the same (Table 4.3). However, changes in corn production and density as well as changes in other types of corn utilization cause daily VTM traveled to change. From 2006 to 2008, daily and annual VTM decrease by 4.6 percent and by 0.7 percent from 2008 to 2010. Although annual and daily VTM change, one way average LOH remains virtually constant, near 28 miles per trip, because the change in miles is very small. Compared to livestock, average LOH is much further due to the large amount of corn consumed by each food processing plant (Table 3.2).

Table 4.3: Truckloads, VTM, and Average LOH for Food Processing Utilization of Corn, by Year

Food Processing Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	241.5	241.5	241.5	0.0%	0.0%
Daily Loads	750	750	750	0.0%	0.0%
Daily VTM	21,657	20,667	20,513	-4.6%	-0.7%
Average LOH (mi)	28.9	27.6	27.3	-4.6%	-0.7%
Annual Loads	262,538	262,538	262,538	0.0%	0.0%
Annual VTM	7,580,089	7,233,341	7,179,481	-4.6%	-0.7%

The number of ethanol plants in Indiana for 2006, 2008, and 2010 are 1, 6, and 12, respectively (Table 3.3). As large users of corn, each additional ethanol plant causes in-state corn consumption to grow. Statewide, daily and annual truckloads to ethanol plants increased by 355.0 percent with annual loads increasing from 38,959 to 177,264 from 2006 to 2008 and then by an additional 133.0 percent to 420,757 from 2008 to 2010 (Table 4.4). Daily and annual VTM increase by 255.9 percent, from 697,699 to 2,483,000, and 164.6 percent to 6,570,592 over the same periods. Although truckloads and VTM increased, one-way average LOH for ethanol remained fairly constant, between 14 and 18 miles. The decrease in average trip miles between 2006 and 2008 can be explained in that ethanol plants that were constructed were located in the northern half of Indiana where corn density is much higher. Average LOH then increased in 2010 as ethanol plants are constructed in close proximity to one another, causing them to compete for corn. Ethanol average LOH is approximately half the distance of food processing. This is because food processing plants are dispersed throughout the entire state (including southern Indiana where corn density is lower) whereas ethanol plants are primarily located in the northern half of Indiana.

Table 4.4: Truckloads, VTM, and Average Trip Miles for Ethanol Utilization of Corn, by Year

Ethanol Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	35.9	163.1	387.1	355.0%	133.3%
Daily Loads	110	501	1,189	355.0%	133.3%
Daily VTM	1,971	7,014	18,561	255.9%	164.6%
Average LOH (mi)	17.9	14.0	15.6	-21.8%	11.5%
Annual Loads	38,959	177,264	420,757	355.0%	133.3%
Annual VTM	697,699	2,483,000	6,570,592	255.9%	164.6%

Because corn is only transported to country elevators after livestock, food processing, and ethanol demands are first met, the addition of ethanol plants in 2008 and 2010 directly affect the amount of corn available to be allocated to elevators. Bushels of corn, daily loads, and annual loads all decrease by 14.5 percent from 2006 to 2008 with annual loads decreasing from 735,264 to 628,907 and then by an additional 34.9 percent to 409,498 from 2008 to 2010 (Table 4.5). Annual VTM decrease from 5,981,891 to 5,297,585 from 2006 to 2008 and decrease to 3,303,842 by 2010. Average LOH increased from 8.1 miles to 8.4 from 2006 to 2008 but then fell from 8.4 to 8.1 from 2008 to 2010. As anticipated, average elevator hauls are short distance.

Table 4.5: Truckloads, VTM, and average LOH for Elevator Utilization of Corn, by Year

Elevator Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	441.2	377.3	245.7	-14.5%	-34.9%
Daily Loads	2,941	2,516	1,638	-14.5%	-34.9%
Daily VTM	23,928	21,190	13,215	-11.4%	-37.6%
Average LOH (mi)	8.1	8.4	8.1	3.5%	-4.2%
Annual Loads	735,264	628,907	409,498	-14.5%	-34.9%
Annual VTM	5,981,891	5,297,585	3,303,842	-11.4%	-37.6%

The only change in soybean crushing utilization of soybeans occurs in the 2008 model with the addition of a biodiesel plant at Claypool, IN in Kosciusko County. Changes between 2006 and 2008 were substantial. Soybean bushels consumed and daily and annual loads increased by 28.1 percent with annual loads increasing from 193,651 to 247,999 (Table 4.6). Daily and annual VTM increased by 41.7 percent with annual VTM from 4,900,579 to 6,942,749 while average LOH increased by 10.6 percent from 25.3 miles to 28.0. With no additional crushing, changes for soybeans from 2008 to 2010 were minor for daily and annual VTM as well as average trips representing only changes in production and density.

Table 4.6: Truckloads, VTM, and Average LOH for Crushers Utilization of Soybeans, by Year

Crushing Facility Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Beans consumed (M bu)	178.2	228.2	228.2	28.1%	0.0%
Daily Loads	553	709	709	28.1%	0.0%
Daily VTM	14,002	19,836	19,612	41.7%	-1.1%
Average LOH (mi)	25.3	28.0	27.7	10.6%	-1.1%
Annual Loads	193,651	247,999	247,999	28.1%	0.0%
Annual VTM	4,900,579	6,942,749	6,864,112	41.7%	-1.1%

Because of the addition of a crushing facility and a decrease in total soybean production, soybeans allocated to country elevators, daily and annual loads, and daily and annual VTM decreased by approximately 40.0 percent with annual loads decreasing from 244,216 to 147,134 and annual VTM from 2,269,230 to 1,363,914 from 2006 to 2008 (Table 4.7). However, this had no effect on average LOH, remaining at 9.3 miles. From 2008 to 2010, crushing capacity remained constant while soybean production increased. This caused an increase in soybeans transported to elevators, daily loads, and annual loads of 9.4 percent during this time. Daily and annual VTM increased by 10.4 percent and average LOH increased by 0.9 percent due to the increase in soybean production.

Table 4.7: Truckloads, VTM, and Average LOH for Elevator Utilization of Soybeans, by Year

Elevator Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Beans consumed (M bu)	146.5	88.3	96.6	-39.8%	9.4%
Daily Loads	977	589	644	-39.8%	9.4%
Daily VTM	9,077	5,456	6,025	-39.9%	10.4%
Average LOH (mi)	9.3	9 .3	9.4	-0.2%	0.9%
Annual Loads	244,216	147,134	161,001	-39.8%	9.4%
Annual VTM	2,269,230	1,363,914	1,506,353	-39.9%	10.4%

4.2 Statewide Outbound Ethanol, DDGS, and Grain Flow

With the addition of 5 ethanol plants from 2006 to 2008, ethanol production and outbound truckloads of ethanol increase by 355.0 percent from 35 to 161 truckloads per day (Table 4.8). With most of the ethanol truck market being either within Indiana or a short distance into bordering states, a majority of the additional VTM are traveled within the borders of Indiana. From 2006 to 2008, daily and annual truck VTM increase 1,446 percent with annual miles increasing from 445,431 to 6,886,564. Initially, as more ethanol plants are constructed, they serve truck markets. In turn, this causes the average LOH to increase by 239.8 percent from 36 to 121 miles. In both 2006 and 2008, total ethanol production is less than the total truck market demand, and thus no ethanol is transported via rail. From 2008 to 2010, six additional ethanol plants are constructed which increases capacity by 133.0 percent. This additional capacity fulfills the truck market demand of 760 million gallons meaning ethanol is also transported by rail in 2010. From 2008 to 2010, daily and annual truckloads increase an additional 67.0 percent with annual loads increasing from 56,875 to 95,000 while daily and annual VTM increase by 86.0 percent with annual VTM increasing from 6,886,564 to 12,835,226. Annual rail tankloads increase from 0 in 2008 to 10,884 in 2010.

Table 4.8: Truckloads, Rail Tankloads, VTM, and Average LOH for Outbound Shipments of Ethanol, by Year

Outbound Ethanol	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Ethanol Production (gallons)	100,000,000	455,000,000	1,060,000,000	355.0%	133.0%
Daily Truckloads	35	161	268	355.0%	67.0%
Daily VTM	1,258	19,454	36,258	1446.0%	86.4%
Average LOH (mi)	36	121	135	239.8%	11.6%
Daily Rail Tankloads	0	0	31	NA	NA
Annual Truckloads	12,500	56,875	95,000	355.0%	67.0%
Annual VTM	445,431	6,886,564	12,835,226	1446%	86%
Annual Rail Tankloads	0	0	10,884	NA	NA

An increase in ethanol production also means an increase in DDGS production. As mentioned earlier in this section, the decrease in corn consumption by livestock is supplemented by the addition of DDGS into livestock diets which is the truck market demand. From 2006 to 2008, DDGS production increased by 355 percent from 38 to 101 truckloads per day (Table 4.9). In 2006, DDGS production is less than the truck market demand therefore, all DDGS is shipped via truck within Indiana. However, in 2008, DDGS production exceeds local truck market demand, causing some DDGS to be shipped out of state via rail. Truckloads of DDGS increase by 169.1 percent from

13,333 to 35,885 and annual rail carloads increase from 0 to 6,195 from 2006 to 2008. During this time, ethanol plants are more dispersed throughout the state causing average LOH for trucks to decrease by 5.0 percent from 64 to 61 miles. DDGS production increases an additional 133.0 percent from 2008 to 2010, with all of the additional DDGS being shipped via rail causing rail carloads to increase 325.5 percent from 6,195 to 26,362. Because the additional ethanol plants constructed are even more dispersed throughout Indiana, the average LOH for trucks decreases an additional 30.3 percent.

Table 4.9. Truckloads, Rail Carloads, VTM, and Average LO for Outbound Shipments of DDGS, by Year

Outbound DDGS	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
DDGS Production (tons)	333,333	1,516,667	3,533,333	355.0%	133.0%
Daily Truckloads	38	101	101	169.1%	0.0%
Daily VTM	2,401	6,139	4,279	155.7%	-30.3%
Average LOH (mi)	64	61	42	-5.0%	-30.3%
Daily Rail Carloads	0	18	74	NA	NA
Annual Truckloads	13,333	35,885	35,885	169.1%	0.0%
Annual VTM	849,918	2,173,138	1,514,683	155.7%	-30.3%
Annual Rail Carloads	0	6,195	26,362	NA	325.5%

Given changes in corn demanded by livestock and ethanol among time periods, outbound shipments of corn from elevators via rail and truck are affected. From 2006 to 2008, total bushels of outbound corn decrease by 14.5 percent as that corn is processed in Indiana (Table 4.10). During this time, daily outbound truckloads decrease by 17.2 percent, from 394 to 327, while rail carloads decrease by 13.8 percent from 401 to 345. VTM decrease by 31.7 percent and average LOH decreases by 17.5 percent. From 2008 to 2010 corn available for outbound shipment decrease an additional 34.9 percent to 245.7 million bushel. Truckloads and VTM decrease by 28.6 percent and 16.8 percent respectively while average LOH increase by 16.6 percent. Rail carloads decreased by 36.4 percent during this time. These changes in outbound corn flows can be explained primarily by the increase in instate consumption of corn from ethanol plants which reduces the amount of corn available for outbound shipment.

Table 4.10. Truckloads, Rail Carloads, VTM, and Average LOH for Outbound Shipments of Corn, by Year

Outbound Corn	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn in Elevator (M bu)	441.2	377.3	245.7	-14.5%	-34.9%
Daily Truckloads	394	327	233	-17.2%	-28.6%
Daily VTM	19,952	13,633	11,340	-31.7%	-16.8%
Average LOH (mi)	51	42	49	-17.5%	16.6%
Daily Rail Carloads	401	345	220	-13.8%	-36.4%
Annual VTM	98,557	81,625	58,253	-17.2%	-28.6%
Annual Truck Miles	4,987,983	3,408,209	2,835,011	-31.7%	-16.8%
Annual Rail Carloads	100,139	86,357	54,887	-13.8%	-36.4%

The only major change in soybean consumption in Indiana is the addition of a biodiesel plant in 2008. This coupled with a decrease in soybean production in 2008 cause soybeans available for shipment from Indiana to decrease by 39.8 percent from 2006 to 2008 (Table 4.11). Truckloads, VTM, and average LOH decrease 29.4, 32.1, and 3.8 percent respectively while rail carloads decrease 42.9 percent during this time. From 2008 to 2010, the only change is an increase in soybean production. This increases the amount of soybeans available for export from Indiana by 9.4 percent. Truckloads increase by 6.8 percent while VTM decrease by 9.2 percent. Average LOH decreases by an additional 15.0 percent during this time. Rail carloads increase by 10.4 percent.

Table 4.11: Truckloads, Rail Carloads, VTM, and Average LOH for Outbound Shipments of Soybeans, by Year

Outbound Soybeans	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Soybeans in Elevator (M bu)	146.5	88.3	96.6	-39.8%	9.4%
Daily Truckloads	148	104	112	-29.4%	6.8%
Daily VTM	6,140	4,168	3,785	-32.1%	-9.2%
Average LOH (mi)	42	40	34	-3.8%	-15.0%
Daily Rail Carloads	129	73	81	-42.9%	10.4%
Annual Truckloads	37,023	26,122	27,908	-29.4%	6.8%
Annual VTM	1,534,974	1,042,077	946,301	-32.1%	-9.2%
Annual Rail Carloads	32,134	18,357	20,264	-42.9%	10.4%

An additional way to examine the results is to focus on relative contributions of different inbound and outbound shipments. Corn utilization by livestock, food processors, ethanol plants, and elevators shift as additional ethanol plants begin production. Livestock’s share of utilization of corn declines from consuming 19.3 percent of the crop in 2006 to 15.4 percent in 2010 (Table 4.12). This occurs due to the incorporation of DDGS in livestock diets. Because no food processing plants are constructed between 2006 and 2010, their share of corn utilization remains relatively constant with small fluctuations due to changes in production. Because the major difference between each model year are additions of ethanol plants, ethanol’s share of corn utilization increases from 4.0 percent in 2006 to 18 percent in 2008 and 37.5 percent by 2010. Elevator utilization of corn declines from 49.5 percent in 2006 to 23.8 percent in 2010 which can be interpreted as a decline in corn available for shipment from Indiana since corn shipped to elevators is assumed to leave Indiana.

Table 4.12: Summary of Corn Utilization by Type, by Year

Corn Utilization	2006		2008		2010	
	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total
Livestock	172.3	19.3%	159.2	16.9%	159.2	15.4%
Food	241.5	27.1%	241.5	25.7%	241.5	23.4%
Ethanol	35.8	4.0%	163.1	17.3%	387.1	37.5%
Elevators	441.2	49.5%	377.3	40.1%	245.7	23.8%
Total	890.8	100%	941.2	100%	1,033.6	100%

Likewise, soybean share between crushing facilities and country elevators shift with the addition of a biodiesel plant in the 2008 model. Crushing facility's share of utilization of soybeans increases from 54.9 percent in 2006 to 72.1 percent in 2008 (Table 4.13). Because of this, elevator's share of utilization declines from 45.1 percent to 27.9 percent during this time. Because no additional facilities are constructed between 2008 and 2010, both crushing and elevator shares of utilization remain relatively constant with small changes due to fluctuations in production.

Table 4.13 Summary of Soybean Utilization by Type, by Year

Soybean Utilization	2006		2008		2010	
	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total
Crushing	178.2	54.9%	228.2	72.1%	228.2	70.3%
Elevators	146.5	45.1%	88.3	27.9%	96.6	29.7%
Total	324.7	100%	316.4	100%	324.8	100%

Annual totals for the state of Indiana for inbound and outbound truckloads and outbound railcars for 2006, 2008, and 2010 are compared in evaluate the overall change between each period (Table 4.14). To further understand changes between each period, annual VTM are also compared for each year (Table 4.15). Inbound truckloads include grain shipments to livestock, food processing, ethanol, crushers, and elevators. Outbound truckloads include corn and soybeans shipped from elevators out of Indiana and ethanol and DDGS shipped from ethanol plants to their respective truck markets.

Table 4.14: Annual Truckloads and Rail Carloads by Commodity, by Year

Annual Truckloads and Rail Carloads (Thousands)	2006	2008	2010
	Truckloads	Truckloads	Truckloads
Livestock	344.5	318.5	318.5
Food Processing	262.5	262.5	262.5
Ethanol	39.0	177.3	420.8
Elevator (corn)	735.3	628.9	409.5
Crushing	193.7	248.0	248.0
Elevator (beans)	244.2	147.1	161.0
Total Inbound	1,819.2	1,782.3	1,820.3
Outbound Ethanol	12.5	56.9	95.0
Outbound DDGS	13.3	35.9	35.9
Outbound Corn	98.6	81.6	58.3
Outbound Beans	37.0	26.1	27.9
Total Outbound	161.4	200.5	217.0
Total Truck Loads	1,980.6	1,982.8	2,037.3
Outbound Ethanol Rail Carloads	0.0	0.0	10.9
Outbound DDGS Rail Carloads	0.0	6.2	26.4
Outbound Corn Rail Carloads	100.1	86.4	54.9
Outbound Soybean Rail Carloads	32.1	18.4	20.3
Total Outbound Rail Carloads	132.3	110.9	112.4

Table 4.15: Annual VTM by Commodity, by Year

Annual VTM (Thousands)	2006	2008	2010
	Miles	Miles	Miles
Livestock	1,767.7	1,522.1	1,504.7
Food Processing	7,580.1	7,233.3	7,179.5
Ethanol	697.7	2,483.0	6,570.6
Elevator (corn)	5,981.9	5,297.6	3,303.8
Crushing	4,900.6	6,942.7	6,864.1
Elevator (beans)	2,269.2	1,363.9	1,506.4
Total Inbound VTM	23,197.2	24,842.7	26,929.1
Outbound Ethanol	445.4	6,886.6	12,835.2
Outbound DDGS	849.9	2,173.1	1,514.7
Outbound Corn	4,988.0	3,408.2	2,835.0
Outbound Beans	1,535.0	1,042.1	946.3
Total Outbound VTM	7,818.3	13,510.0	18,131.2
Total VTM	31,015.5	38,352.7	45,060.4

Overall, inbound truckloads within Indiana remain fairly constant with a small increase from 1,819.2 to 1,820.3 thousand from 2006 to 2010 while annual VTM increase from 23,197.2 to 26,929.1 thousand. Although this is not a large overall change, major changes within commodity types do occur. Annual truckloads of corn to livestock decrease from 344.5 to 318.5 thousand truckloads which account for a decline in VTM of 263.0 thousand miles from 2006 to 2010. However, a major shift occurs between corn transported to elevators to corn transported to ethanol plants. From 2006 to 2008, annual truckloads of corn to ethanol plants increase from 39.0 to 177.3 thousand which is an increase in VTM from 697.7 to 2,483.0 thousand. Annual elevator truckloads decreased from 735.3 to 628.9 thousand loads which is a decrease in VTM from 5,981.9 to 5,297.6 thousand. This trend continued from 2008 to 2010 with annual truckloads of corn to ethanol plants increasing to 420.8 thousand and

VTM to 6,570.6 thousand. Likewise truckloads of corn to elevators decreased to 409.5 thousand and VTM to 3,303.8 thousand. A shift also occurs between soybeans transported to elevators and crushing facilities. Annual truckloads of soybeans to crushers increase from 193.7 to 248.0 thousand and VTM from 4,900.6 to 6,942.7 thousand from 2006 to 2008. During this time, annual truckloads of soybeans to elevators decreased from 244.2 to 147.1 thousand and VTM from 2,269.2 to 1,363.9 thousand.

Total outbound truckloads increase from 161.4 to 217.0 thousand from 2006 to 2010. Additionally, total outbound annual VTM increase from 7,818.3 to 18,131.2 during this time. This can be attributed to less outbound grain and more outbound ethanol and DDGS, which travel further to their respective truck markets. From 2006 to 2010, annual outbound truckloads of corn decrease from 98.6 to 58.3 thousand and soybeans from 37.0 to 27.9 thousand. VTM decrease from 4,988.0 to 2,835.0 thousand and 1,535.0 to 946.3 thousand for corn and soybeans, respectively.

Total annual outbound rail carloads slightly decrease from 132.3 to 112.4 thousand from 2006 to 2010. However, during this time there is a shift from outbound railcars of grain to more railcars with ethanol and DDGS. During this time, rail carloads of corn decline from 100.1 to 54.9 thousand and beans from 32.1 to 20.3 thousand. Ethanol rail carloads increased from 0 in 2008 to 10.9 thousand in 2010. DDGS increased from 0 rail carloads in 2006 to 26.4 thousand in 2010.

4.3 Results for Counties with Biofuel Plants

Changes between each model year are triggered by the addition of biofuel plants. Thus, it is likely much of the change that occurs between each year is concentrated in counties where biofuel plants are constructed. Truckloads of corn delivered to ethanol plants increases by 704.3 percent from 2006 to 2008 from 9.2 to 74.2 thousand and by 100.5 percent from 2008 to 2010 to 148.8 thousand. VTM increase from 345.4 thousand in 2006, to 1,436.3 thousand in 2008 and to 3,493.4 thousand in 2010 (Tables 4.16 and 4.17). Truckloads of corn shipped to elevators decline by 32.9 percent from 2006 to 2008 from 140.0 to 93.9 thousand and by an additional 80.7 percent from 2008 to 2010 to 18.1 thousand. VTM decreased by 30.1 percent from 1,184.0 to 827.6 thousand from 2006 to 2008 and by an additional 81.2 percent to 155.9 thousand from 2008 to 2010. From 2006 to 2008, soybean truckloads transported to crushing facilities increase by 109.6 percent from 4.1 to 8.7 thousand but then remains relatively constant from 2008 to 2010 due to no additional crushing facilities beginning production during this time. VTM increase from 214.0 to 790.7 thousand during this time. From 2006 to 2008, truckloads of soybeans shipped to elevators declines by 54.9 percent from 57.9 to 26.1 thousand and VTM decrease by 55.2 percent from 781.5 to 349.8 thousand. Truckloads and VTM increase slightly from 2008 to 2010 due to increases in production.

Table 4.16: Annual Inbound Truckloads for Counties with Biofuel Plants, by Year

Inbound Trucks Within Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Corn to Livestock	80.2	76.1	76.1	-5.0%	0.0%
Corn to Food	4.4	4.4	4.4	0.0%	0.0%
Corn to Ethanol	9.2	74.2	148.8	704.3%	100.5%
Corn to Elevator	140.0	93.9	18.1	-32.9%	-80.7%
Beans to Crusher	4.1	8.7	8.9	109.6%	2.5%
Beans to Elevator	57.9	26.1	30.7	-54.9%	17.8%
Total	295.8	283.3	287.0	-4.2%	1.3%

Table 4.17: Annual VTM for Counties with Biofuel Plants, by Year

Inbound VTM Within Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Corn to Livestock	431.0	386.5	381.3	-10.3%	-1.4%
Corn to Food	24.3	23.1	22.7	-4.9%	-1.5%
Corn to Ethanol	345.4	1,436.3	3,493.4	315.9%	143.2%
Corn to Elevator	1,184.0	827.6	155.9	-30.1%	-81.2%
Beans to Crusher	214.0	790.7	767.8	269.5%	-2.9%
Beans to Elevator	781.5	349.8	415.6	-55.2%	18.8%
Total	2,980.2	3,813.9	5,236.7	28.0%	37.3%

Outbound truckloads of ethanol increase from 2006 to 2008 and from 2008 to 2010 by 355.0 percent from 12.5 to 56.9 thousand and 67.0 percent to 95.0 thousand respectively (Table 4.18). VTM increase by 1,446.0 percent from 445.4 to 6,886.6 thousand from 2006 to 2008 and an additional 86.4 percent to 12,835.2 thousand (Table 4.19). Likewise, outbound shipments of DDGS increase by 169.1 percent from 13.3 to 35.9 thousand and VTM by 155.7 percent from 849.9 to 2,173.1 thousand from 2006 to 2008 and remain constant through 2010 due to truck market demands being satisfied. Because of the decline in corn and soybeans utilized by elevators, outbound truckloads of corn decrease by 28.3 percent from 12.7 to 9.1 thousand from 2006 to 2008 while VTM decrease by 43.9 percent from 820.8 to 460.1 thousand. From 2008 to 2010, truckloads decrease an additional 78.1 percent to 2.0 thousand and VTM decrease an additional 65.1 percent to 160.5 thousand. From 2006 to 2008, truckloads of beans decrease by 75.9 percent from 7.2 to 1.7 thousand and VTM by 76.2 percent from 426.5 to 101.3 thousand.

Table 4.18: Annual Outbound Trucks from Indiana for Counties with Biofuel Plants, by Year

Outbound Trucks From Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	12.5	56.9	95.0	355.0%	67.0%
Outbound DDGS	13.3	35.9	35.9	169.1%	0.0%
Outbound Corn From Elevators	12.7	9.1	2.0	-28.3%	-78.1%
Outbound Beans From Elevators	7.2	1.7	2.2	-75.9%	27.4%
Total	45.7	103.6	135.1	126.5%	30.4%

Table 4.19: Annual Outbound VTM for Counties with Biofuel Plants, by Year

Outbound VTM From Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	445.4	6,886.6	12,835.2	1446.0%	86.4%
Outbound DDGS	849.9	2,173.1	1,514.7	155.7%	-30.3%
Outbound Corn From Elevators	820.8	460.1	160.5	-43.9%	-65.1%
Outbound Beans From Elevators	426.5	101.3	120.2	-76.2%	18.6%
Total	2,542.7	9,621.2	14,630.6	278.4%	52.1%

Ethanol is shipped via rail in the 2010 model going from 0 annual rail carloads in 2008 to 10.9 thousand in 2010 (Table 4.20). Likewise, DDGS is shipped by rail starting in 2008 going from 0 annual carloads in 2006 to 6.2 thousand in 2008 and increasing an additional 325.5 percent to 26.4 annual carloads by 2010. Rail carloads of corn decrease by 33.7 percent from 2006 to 2008 from 20.7 to 13.7 thousand and by 81.2 percent to 2.6 thousand from 2008 to 2010. Likewise, soybean rail carloads decreased by 78.4 percent from 8.0 to 1.7 thousand from 2006 to 2008.

Table 4.20: Annual Outbound Rail Carloads from Counties with Biofuel Plants, by Year

Outbound Rail (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	0.0	0.0	10.9	NA	NA
Outbound DDGS	0.0	6.2	26.4	NA	325.5%
Outbound Corn	20.7	13.7	2.6	-33.7%	-81.2%
Outbound Soybeans	8.0	1.7	2.2	-78.4%	27.4%
Total	28.7	21.6	42.0	-24.6%	94.3%

4.4 Results for Counties Adjacent to Biofuel Production Counties

Much of the state wide change is observed in counties with biofuel production. The draw areas for biofuel plants extend into adjacent counties therefore, these county's grain flows and transportation systems are also likely affected. Truckloads of corn to ethanol plants increase by 246.7 percent from 2006 to 2008 increasing from 29.7 to 103.1 thousand. VTM also increase during this time by197.1 percent from 352.3 to 1,046.7 thousand. From 2008 to 2010 truckloads increase an additional 163.9 percent to 272.0 thousand and VTM by 194.0 percent to 3,077.2 thousand. Likewise, truckloads of soybeans increase by 42.9 percent from 116.2 to 166.0 thousand while VTM also increase by 55.1 percent from 2,671.5 to 4,143.3 thousand from 2006 to 2008.

Inbound truckloads of corn to elevators decrease by 21.2 percent from 335.8 to 264.8 thousand from 2006 to 2008 and 46.5 percent to 141.7 thousand from 2008 to 2010 (Table 4.21). VTM decrease by 17.8 percent from 2,680.2 to 2,202.5 thousand from 2006 to 2008 and by an additional 50.0 percent to 1,100.7 thousand from 2008 to 2010. From 2006 to 2008, inbound truckloads of soybeans decrease by 48.7 percent from 115.2 to 59.1 thousand while VTM decrease by 48.4 percent from 1,058.7 to 546.6 thousand.

Table 4.21: Annual Inbound Truckloads for Counties Adjacent to Biofuel Production, by Year

Inbound Trucks Within Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Corn to Livestock	138.0	129.2	129.2	-6.4%	0.0%
Corn to Food	223.2	223.2	223.2	0.0%	0.0%
Corn to Ethanol	29.7.	103.1	272.0	246.7%	163.9%
Corn to Elevator	335.8	264.8	141.7	-21.2%	-46.5%
Beans to Crusher	116.2	166.0	165.8	42.9%	-0.1%
Beans to Elevator	115.2	59.1	66.3	-48.7%	12.1%
Total	958.1	945.4	998.2	-1.3%	5.6%

Table 4.22: Annual Inbound VTM for Counties Adjacent to Biofuel Production, by Year

Inbound Trucks Within Indiana (Thousand)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Corn to Livestock	637.5	562.4	554.6	-11.8%	-1.4%
Corn to Food	6,876.9	6,732.9	6,589.3	-2.1%	-2.1%
Corn to Ethanol	352.3	1,046.7	3,077.2	197.1%	194.0%
Corn to Elevator	2,680.2	2,202.5	1,100.7	-17.8%	-50.0%
Beans to Crusher	2,671.5	4,143.3	4,105.6	55.1%	-0.9%
Beans to Elevator	1,058.7	546.6	629.9	-48.4%	13.4%
Total	14,277.2	15,234.6	16,047.2	6.7%	5.3%

Because less grain is shipped to elevators, outbound loads of corn and soybeans from elevators leaving Indiana are also affected. Outbound truckloads of corn decline by 15.5 percent from 31.5 to 26.6 thousand from 2006 to 2008 and an additional 43.4 percent to 15.1 thousand from 2008 to 2010 (Table 4.23). VTM also decrease from 2006 to 2008 by 33.7 percent from 2,126.4 to 1,410.4 thousand (Table 4.24). From 2008 to 2010, VTM decrease an additional 32.5 percent to 951.4 thousand. From 2006 to 2008, truckloads of soybeans leaving the state also decline by 33.9 percent from 13.1 to 8.7 thousand and VTM decrease by 34.7 percent from 630.0 to 411.6 thousand. Likewise, rail carloads of corn leaving Indiana decrease from 2006 to 2008 and from 2008 to 2010 by 22.1 percent from 49.3 to 38.4 thousand and 47.0 percent to 20.3 thousand respectively (Table 4.25). Soybean rail carloads are down 46.9 percent from 16.3 to 8.7 thousand from 2006 to 2008.

Table 4.23: Annual Outbound Truckloads for Counties Adjacent to Biofuel Production, by Year

Outbound Trucks From Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	0.0	0.0	0.0	NA	NA
Outbound DDGS	0.0	0.0	0.0	NA	NA
Outbound Corn From Elevators	31.5	26.6	15.1	-15.5%	-43.4%
Outbound Beans From Elevators	13.1	8.7	9.6	-33.9%	10.3%
Total	44.6	35.3	24.6	-20.9%	-30.2%

Table 4.24: Annual Outbound VTM for Counties Adjacent to Biofuel Production, by Year

Outbound Trucks From Indiana (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	0.0	0.0	0.0	NA	NA
Outbound DDGS	0.0	0.0	0.0	NA	NA
Outbound Corn From Elevators	2,126.4	1,410.4	951.4	-33.7%	-32.5%
Outbound Beans From Elevators	630.0	411.6	376.5	-34.7%	-8.5%
Total	2,756.5	1,822.0	1,327.9	-33.9%	-27.1%

Table 4.25: Annual Outbound Rail Carloads for Counties Adjacent to Biofuel Production, by Year

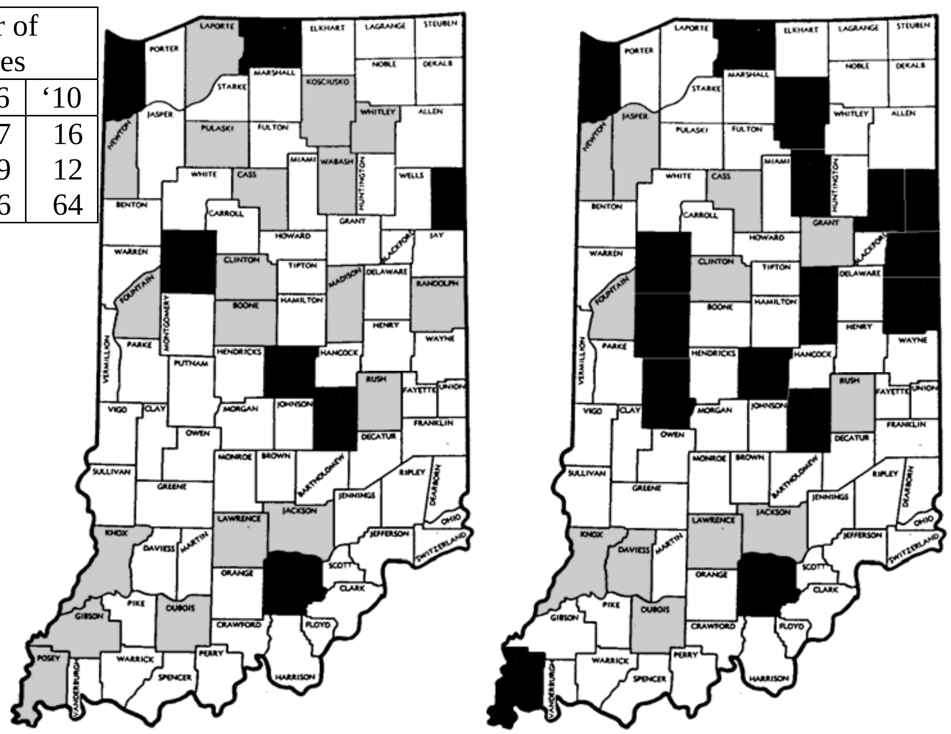
Outbound Rail (Thousands)	Model			% Change From:	% Change From:
	2006	2008	2010	06 to 08	08 to 10
Outbound Ethanol	0.0	0.0	0.0	NA	NA
Outbound DDGS	0.0	0.0	0.0	NA	NA
Outbound Corn	49.3	38.4	20.3	-22.1%	-47.0%
Outbound Soybeans	16.3	8.7	9.6	-46.9%	10.3%
Total	65.6	47.0	29.9	-28.3%	-36.5%

4.4 Results Comparing VTM among all Counties

To better understand which areas of Indiana experience the most change in transportation requirements due to biofuel expansion, county level comparisons of VTM are done (Appendix E). Annual VTM for each county are compared between 2006 and 2010 in Figure 4.1. Black counties indicate total annual VTM greater than 1 million while grey counties indicate annual VTM between 300,000 and 1 million. White counties have annual VTM less than 300,000.

2006 2010

Number of Counties		
	'06	'10
Black	7	16
Grey	19	12
White	66	64



- Black= VTM greater than 1 Million
- Grey= VTM between 300,000 and 1 Million
- White= VTM Less than 300,000

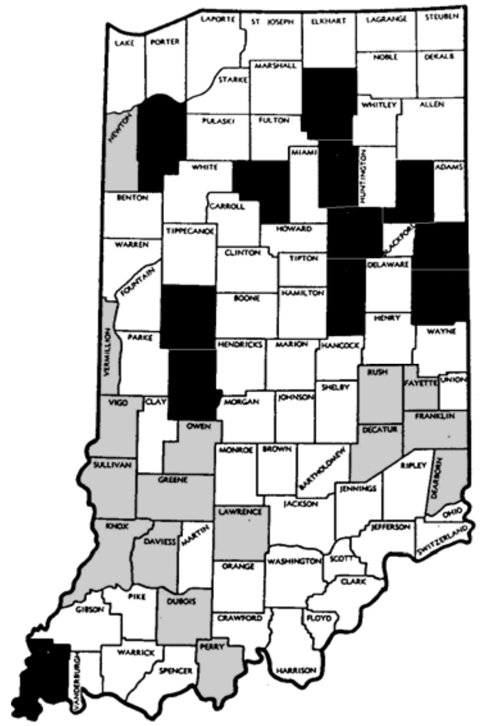
Figure 4.1: Annual VTM by County in Indiana for 2006 and 2010

From 2006 to 2010, an additional nine counties have total VTM over 1 million. Of these nine counties, five were coded grey and four coded white in 2006. Overall, there are seven less grey coded counties and two additional white coded counties from 2006 to 2010.

VTM increases from 2006 to 2010 are concentrated in East Central Indiana in which all counties that become black coded in 2010 experience construction of a biofuel plant. Because of the concentration of biofuel plant construction, and thus increases in VTM in the East Central region of Indiana, much of the additional truck traffic as well changes in inbound and outbound grain and ethanol flows reported for biofuel counties (Tables 4.6, 4.17, 4.18, 4.10, 4.20) are experienced in this region.

An additional method of illustrating which counties are most affected by biofuel expansion is to examine which counties have larger percentage increases in VTM from 2006 to 2008 (Figure 4.2). Black counties indicate a percentage change greater than 100 percent while grey counties indicate a percentage change between 10.0 and 34.3 percent. No county experienced an increase in VTM between 34.4 and 100 percent during this time period. White counties indicate less than 10.0 percent increase in VTM during this time period.

Counties with Biofuel Plant Construction, '06-'10	
County	% Change
Montgomery	3,240.6%
Jay	1,617.0%
Wells	1,433.3%
Putnam	796.4%
Posey	664.0%
Kosciusko	503.9%
Randolph	351.8%
Wabash	159.7%
Madison	155.8%
Jasper	136.4%
Grant	120.8%
Cass	116.8%



- Black= Percent Change in VTM greater than 100%
- Grey= Percent Change in VTM 10-35%
- White= Percent Change in VTM less than 10%

Figure 4.2: Percent Increase in VTM from 2006 to 2010 by County

All counties experiencing 100 percent or more growth in terms of VTM have ethanol plants constructed between 2006 and 2010. Many of these counties are also located in the East Central region of Indiana indicating again that much of the change in truck traffic and commodity flows reported for biofuel counties will be concentrated in this region of the state.

4.5 Conclusion

Assumptions were made in the development of this model. Therefore, the results must be interpreted with these assumptions in mind. Chapter 5 examines conclusions that can be drawn given the context of the assumptions. Limitations with these assumptions as well as areas for future research are also discussed.

CHAPTER 5: CONCLUSION

5.1 Overview

Ethanol and biodiesel producers constantly deal with transportation issues from allocating feedstock to shipping end products to destination points. As more ethanol plants are constructed, local roads could become more congested. This presents important questions transportation policy makers will face. The objective of this thesis is to determine how the entry of biofuel plants affects inbound and outbound transportation flows of corn, soybeans, DDGS and ethanol at the county level in Indiana. To accomplish this, transportation flows of corn, soybeans, ethanol, and DDGS were examined for three time periods, 2006 (baseline), 2008 (short term adjustments), and 2010 (long term adjustments).

The biofuel industry in the United States has experienced rapid growth in the last decade. The ethanol industry alone has increased production capacity from just over 1 billion gallons in 1997 to nearly 8.5 billion in April of 2008, with most of the growth since 2005. Furthermore, the ethanol industry will likely experience additional growth through 2010 in order to meet the Renewable Fuels Standard. Likewise, ethanol producers in the state of Indiana plan to expand capacity from 100 million gallons in 2006 to over 1 billion by 2010, and also added a biodiesel plant in 2007 with a capacity of 88 million gallons. Growth in this industry has provided opportunities not only to the biofuels industry but also to agriculture and transportation industries.

Additional demand for grain from biofuel expansion affects decisions farmers must make. Rather than shipping grain short distances to country elevators, they have an additional option of shipping grain directly to biofuel plants which could mean longer haul distances. This means it is likely less grain will be handled by elevators and that grain will be shipped through new transportation routes to biofuel plants. It is likely that users of ethanol and DDGS also will be affected. Much more product in terms of volume will become available as more plants are constructed. This means as additional plants begin production, ethanol and DDGS producers and consumers face transportation decisions such as which mode of transportation, truck or rail, they are best suited for.

As more grain is hauled to biofuel plants and more ethanol and DDGS is transported to demand points, it is apparent that transportation routes will likely change. The addition of biofuel plants also presents an opportunity for rural economic development.

5.2 Model and Results

Distance minimizing transportation linear programming models were developed to allocate grain, ethanol, and DDGS between production and consumption points. Output from these models was used in an Excel spreadsheet model to estimate transportation requirements. This procedure was performed at the county level for all counties in Indiana. The models described were used for three separate time periods

(2006, 2008, and 2010) using forecasted data when necessary. End results from the Excel spreadsheet model include truckloads, VTM, average LOH, and rail carloads required to transport each commodity type. Results were reported at the county level for every county in Indiana. Because the major change between time periods is the addition of biofuel plants, the difference in results between each year can be largely attributed to the additional biofuel plants introduced.

Statewide results show an increase in corn production between 2006 and 2008 and between 2008 and 2010 of 5.3 percent and 2.5 percent respectively. Soybean production declines by 1.7 percent but increases by 3.1% during this time. Thus, volume of total grain is projected to increase between each time period. Ethanol production and thus, corn utilization, gallons of ethanol produced, and tons of DDGS produced, increase by 355.0 percent and 133.0 percent between each respective period with gallons of ethanol produced increasing from 100 MGY in 2006 to 455 MGY in 2008 and 1,060 MGY by 2010. From 2006 to 2008, annual truckloads of corn to ethanol plants increased from 40.0 to 177.3 thousand and VTM increased from 697.7 thousand to 2.48 million miles. From 2008 to 2010, annual truckloads of corn to ethanol plants increased to 420.8 thousand while VTM increased to 6.57 million miles. Soybean crushing capacity also increases by 28.1 percent from 178.2 to 228.2 million bushels from 2006 to 2008 due to the addition of a biofuel plant in Kosciusko County. Because of the increase in grain and biofuel production, total VTM increase by 23.7 percent from 31.0 to 38.6 million and by an additional 17.5 percent to 45.0 million from 2008 to 2010.

Most of the differences in truckloads and miles between each time period are because of additional biofuel plants. Thus, it is likely that differences are concentrated in counties with biofuel plants. Truckloads of corn to ethanol plants increase by 704.3 percent from 9.2 to 74.2 thousand and by an additional 100.5 percent to 148.8 thousand from 2006 to 2008 and 2008 to 2010 respectively. VTM also increase by 315.9 percent from 345.4 to 1,136.3 thousand from 2006 to 2008 and by an additional 143.2 percent to 3,493.4 thousand by 2010. Likewise, truck loads of soybeans to crushing facilities increase by 109.6 percent from 4.1 to 8.7 thousand while VTM increase by 269.5 percent from 214.0 to 790.7 thousand from 2006 to 2008.

In counties with biofuel plants, corn and soybean truckloads transported to elevators decrease by 32.9 percent from 140.0 to 93.9 thousand and 54.9 percent from 57.9 to 26.1 thousand respectively from 2006 to 2008. VTM for corn and soybeans transported to elevators also decrease by 30.1 percent from 1.18 million to 827.6 thousand and 55.2 percent from 781.5 to 349.8 thousand respectively. From 2008 to 2010, truckloads of corn to elevators declined an additional 80.7 percent to 18.1 thousand and VMT decreased by 81.2 percent to 155.9 thousand. Likewise, truckloads of corn transported from elevators out of Indiana decrease 28.3 percent from 12.7 to 9.1 thousand from 2006 to 2008 and 78.1 percent to 2.0 thousand from 2008 to 2010. Likewise, VTM decrease by 43.9 percent from 820.8 to 460.1 thousand and by an additional 65.1 percent to 160.5 thousand for each respective time period change. Rail carloads of corn are down 33.7 percent from 20.7 to 13.7 thousand and 81.2 percent to 2.6 thousand during these periods as well. Soybean truckloads and rail carloads decline 46.2 percent from 426.5 to 101.3 thousand and 78.4 percent from 8.0 to 1.7 thousand respectively from 2006 to 2008.

Grain draw areas for biofuel plants usually extend into adjacent counties thus affecting grain flows in these counties. Truckloads of corn transported to ethanol plants in an adjacent county increase by 246.7 percent from 29.7 to 103.1 thousand while VTM increase by 197.1 percent from 352.3 to 1,046.7 thousand from 2006 to 2008. From 2008 to 2010, truckloads of corn increase 163.9 percent to 272.0 thousand and VTM by 194.0 percent to 3,077.2 thousand. Corn transported to and from elevators declines between 2006 and 2008 as well as from 2008 to 2010. Truckloads of corn shipped to elevators decline by 21.2 percent and 46.5 percent between each respective time period. Truckloads and rail carloads leaving elevators decline by 15.5 percent and 22.1 percent respectively from 2006 to 2008 and an additional 43.4 percent and 47.0 percent respectively from 2008 to 2010. Likewise, soybean truckloads to elevators decline by 48.7% from 2006 to 2008. During this time, outbound truckloads and rail car loads of soybeans from elevators decline by 33.9 percent and 46.9 percent respectively.

5.3 Conclusions

Three main conclusions are based on results from this research:

1. Truck traffic in Indiana associated with grain, ethanol, and DDGS movements will increase by 14.04 million VTM or 45.3 percent due to biofuel expansion.
2. Elevators will handle less grain.
3. The rail industry will have less grain to handle, but more ethanol and DDGS.

First, results show that both statewide total truckloads and VTM increase between each time period with most of this change occurring in counties with biofuel plants and adjacent counties. Results also show that truckloads of grain to elevators decline between each period. These results imply that a shift is occurring from grain being shipped to elevators to grain being shipped directly to biofuel plants. Compared to elevators, biofuel plants average LOH for grain is further by approximately 10 miles per load. This means that grain is being transported by truck further distance in 2008 and 2010 than in 2006. Although it is not entirely clear from this research which roads will be most affected, it is likely that some of the increased truck traffic will occur on secondary roads given the rural nature of grain production and biofuel plant location in Indiana.

Furthermore, as more grain is transported directly to biofuel plants and less to elevators, transportation flows of corn will also change. Historically, grain transported to elevators usually maintains similar transportation flows year to year. Shipments of grain to elevators are also very seasonal being concentrated during grain harvest season. Because biofuel plants demand grain consistently throughout the year, grain transportation traffic will be less seasonal compared to elevator grain flows.

Second, the results show a significant decline in bushels of corn, approximately 195.5 million bushels, and soybeans, approximately 49.9 million bushels, transported to elevators. With most elevators running on small profit margins per bushel of grain handled, a large reduction in volume of grain going through an elevator could lead to significant affects in profits generated by elevators. Although this study does not examine the direct effects of biofuel production on elevator profitability, it is possible to infer that some elevators could shut down due to the reduction in grain handled by elevators. From results from this study, it also remains uncertain what role elevators will have during biofuel expansion. The effects of biofuel expansion experienced by elevators throughout the state will be determined by several factors. One possible factor is an elevator's location in proximity to a biofuel plant. Another factor is that biofuel plants may not have sufficient storage capabilities on site, thereby providing opportunity for nearby elevators to assist with grain origination to the plant.

A decline in grain being shipped to elevators also means that less grain will be transported from elevators out of state. Truckloads transporting grain from elevators out of Indiana usually travel longer distances compared to trucks delivering corn to processing plants and elevators. A reduction in truckloads from elevators means less long haul truckloads within Indiana. However, a majority of grain leaving Indiana from elevators happens via rail which means the rail industry will be affected as well.

Results show a reduction in rail carloads of grain leaving Indiana but an increase in loads of ethanol and DDGS. This means that the reduction in grain being transported by rail is partially offset by the increase in ethanol and DDGS. Combined loads of corn, soybeans, ethanol, and DDGS decline by 15.0 percent from 2006 to 2010. Additionally, transportation of grain by rail is seasonal where ethanol and DDGS most likely will not be. Although the change in total loads is relatively small, the rail industry will need to adapt to differences in transporting ethanol and DDGS rather than grain. It should be noted that both ethanol and DDGS have issues in being transported by rail. Unit train receiving destination points for ethanol are limited, therefore logistical constraints will likely play a factor in ethanol shipments by rail. DDGS is very bulky in nature and solidifies in rail cars during transport. This increases the time and labor requirement to load and unload cars with DDGS. The results of this study do not take these factors into account and it remains unclear exactly how this will affect rail transportation.

5.4 Future Research

As a first examination of impacts biofuel expansion will have on Indiana transportation requirements, this research can be extended. The results also indicate possible areas for future research.

As with any model, the results of this model are a product of the assumptions made. Assumptions made in this research with regard to truck capacities leave room for further development. For example, it is unlikely that all trucks delivering grain to food processing and ethanol plants have a 920 bushel capacity, but rather are a mix of different capacity trucks. This is true for all inbound grain and outbound grain, ethanol, and DDGS trucks. Incorporating a more accurate distribution of different truck capacities will provide more accurate calculations for truckloads and miles. Different truck sizes also damage roadways differently. A more accurate estimation of truckloads and VTM for different truck sizes allows for the possibility of better analyzing road damage and upkeep requirements due to biofuel expansion.

Ethanol and DDGS truck markets are assumed to be satisfied before rail shipments are considered. Most ethanol plants being constructed in Indiana have rail access. Therefore, it is likely they will use rail access regardless of truck market demand. It is more likely that the decision to ship outbound ethanol and DDGS will be based primarily on costs and price offered by a demand location. If a gasoline blending terminal is offering higher prices for ethanol and the costs to transport via rail are competitive relative to the truck market, then an ethanol plant is likely to engage in rail shipments regardless of the status of truck market demand. Further research could incorporate a decision variable that incorporates ethanol and DDGs prices, transport costs, and location in terms of rail and highway access to determine the distribution of outbound rail and truck shipments of ethanol and DDGS.

This research assumes historic cropping patterns will hold true through 2010. However, this research does not include the effects that biofuel expansion has on crop prices, which in turn could affect farmers' decisions on crop acreage. It remains unclear at this time exactly how the agriculture industry will adapt to increasing commodity prices (specifically corn and soybeans). As this research is used in the future, it should be known that results could be altered based on shifts in corn and soybean production acres.

The results of this research also provide opportunity for future research topics. As corn based ethanol production is expected to peak around 2010, other production methods are being researched including cellulosic ethanol production. Although it is not known when this production method can be used commercially, it is not too early to examine possible transportation issues that could arise. This research presents the opportunity to examine cellulosic ethanol production and possible transportation issues or effects it could experience in the future. This type of knowledge ahead of time could prove critical in the planning stages for future cellulosic ethanol plants. It also would be beneficial to transportation planners to plan ahead when a cellulosic ethanol plant is being constructed.

This research examines inbound grain flows and outbound grain, ethanol, and DDGS on a county level basis and how the flows are affected when a biofuel plant is introduced. The results of this research indicate changes in transportation flows due to additional biofuel plants being constructed. However, it is difficult to examine the affects an individual plant has from the results. Future research could develop a similar model to this, but also examine an individual plant. This would help local transportation planners better prepare and allocate funds for infrastructure development and upkeep. It would also benefit ethanol plants in modeling and planning transportation modes.

The results from this research provide information about changes in terms of truckloads and VTM due to biofuel production. One shortcoming is this model does not address which roadways will be affected. Future research could incorporate Geographic Information Systems (GIS) to model which transportation routes are affected and which new transportation routes are taken. This would especially aid transportation planners in the future. However, given aggregate impacts and knowledge of plant locations, planners are able to make informed judgments in using information from this research to estimate local transportation infrastructure impacts.

The nature of this research and data included in the model is subject to changes in market conditions and policy. As market conditions change, assumptions that are affected need to be updated. Likewise, if policy changes that affect markets of interest, assumptions need to be updated if possible.

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APPENDICES

Appendix A: Elevator Grain Designation of Shipment Mode

County	Grain Elevators	Mode	Rail	Truck
Adams	2,198,481	S	1,827,898	370,583
Allen	10,502,280	R	9,977,166	525,114
Bartholomew	0	T	0	0
Benton	5,670,526	S	4,714,684	955,842
Blackford	2,203,658	R	2,093,475	110,183
Boone	12,127,724	S	10,083,435	2,044,289
Brown	0	T	0	0
Carroll	0	R	0	0
Cass	12,404,735	R	11,784,498	620,237
Clark	0	S	0	0
Clay	8,462,110	S	7,035,709	1,426,401
Clinton	0	S	0	0
Crawford	0	T	0	0
Daviess	6,777,226	S	5,634,835	1,142,391
De Kalb	4,974,069	R	4,725,366	248,703
Dearborn	851,910	S	708,309	143,601
Decatur	5,868,568	S	4,879,343	989,225
Delaware	8,658,907	R	8,225,962	432,945
Dubois	0	T	0	0
Elkhart	0	S	0	0
Fayette	4,904,063	S	4,077,418	826,645
Floyd	0	T	0	0
Fountain	17,015,173	R	16,164,415	850,759
Franklin	3,810,750	T	0	3,810,750
Fulton	7,104,212	S	5,906,703	1,197,509
Gibson	14,810,876	S	12,314,307	2,496,570
Grant	5,995,898	S	4,985,210	1,010,688
Greene	3,952,988	S	3,286,660	666,329
Hamilton	0	T	0	0
Hancock	0	T	0	0
Harrison	0	T	0	0
Hendricks	0	T	0	0
Henry	10,172,188	S	8,457,531	1,714,657
Howard	8,186,409	R	7,777,088	409,320
Huntington	8,388,082	S	6,974,160	1,413,923

Jackson	0	T	0	0
Jasper	0	R	0	0
Jay	2,359,911	S	1,962,117	397,794
Jefferson	0	T	0	0
Jennings	0	T	0	0
Johnson	0	R	0	0
Knox	16,147,306	S	13,425,464	2,721,843
Kosciusko	9,242,180	S	7,684,288	1,557,892
La Porte	3,115,444	S	2,590,295	525,149
La Grange	3,422,998	S	2,846,007	576,992
Lake	0	T	0	0
Lawrence	0	T	0	0
Madison	11,916,122	S	9,907,501	2,008,620
Marion	0	R	0	0
Marshall	0	R	0	0
Martin	0	T	0	0
Miami	6,863,528	R	6,520,352	343,176
Monroe	0	T	0	0
Montgomery	0	R	0	0
Morgan	6,390,390	S	5,313,205	1,077,185
Newton	12,462,360	S	10,361,664	2,100,696
Noble	6,793,958	S	5,648,746	1,145,212
Ohio	0	T	0	0
Orange	0	T	0	0
Owen	1,742,843	T	0	1,742,843
Parke	9,043,553	S	7,519,142	1,524,411
Perry	483,900	T	0	483,900
Pike	4,149,644	S	3,450,166	699,478
Porter	0	R	0	0
Posey	13,482,449	S	11,209,803	2,272,646
Pulaski	12,848,201	S	10,682,466	2,165,735
Putnam	8,144,220	R	7,737,009	407,211
Randolph	10,164,184	S	8,450,876	1,713,308
Ripley	4,798,795	T	0	4,798,795
Rush	12,209,755	S	10,151,639	2,058,116
Scott	0	T	0	0
Shelby	13,488,409	S	11,214,758	2,273,650
Spencer	5,138,144	T	0	5,138,144

St. Joseph	0	T	0	0
Starke	8,714,299	S	7,245,388	1,468,911
Steuben	4,486,937	S	3,730,604	756,333
Sullivan	9,764,936	R	9,276,690	488,247
Switzerland	0	T	0	0
Tippecanoe	0	T	0	0
Tipton	10,417,018	R	9,896,167	520,851
Union	4,591,713	S	3,817,719	773,994
Vanderburgh	0	R	0	0
Vermillion	3,629,297	S	3,017,531	611,766
Vigo	7,444,457	S	6,189,595	1,254,862
Wabash	5,448,535	S	4,530,112	918,423
Warren	0	T	0	0
Warrick	4,989,856	T	0	4,989,856
Washington	0	T	0	0
Wayne	8,091,097	S	6,727,236	1,363,862
Wells	8,638,290	S	7,182,192	1,456,098
White	0	S	0	0
Whitley	6,811,894	S	5,663,659	1,148,235

Appendix B: 2002 Census Sales for Indiana, by Animal Type, by County

County	Total Animal Sales (000$)	Dairy Sales (000$)	Cattle Sales (000$)	Hog Sales (000$)	Poultry Sales (000$)
Adams	59,865	10,871	7,390	26,861	14,302
Allen	18,686	(D)	6,540	6,110	15
Bartholomew	7,223	2,214	1,905	2,899	2
Benton	2,411	0	852	1,513	(D)
Blackford	5,670	49	487	5,065	1
Boone	10,785	512	1,738	6,686	1,534
Brown	678	(D)	(D)	9	2
Carroll	43,786	130	2,533	40,793	7
Cass	22,795	5,028	3,591	13,963	(D)
Clark	5,767	(D)	2,280	296	1,976
Clay	5,744	2,190	(D)	1,394	(D)
Clinton	37,284	242	467	32,676	(D)
Crawford	2,273	894	1,254	19	(D)
Daviess	71,403	(D)	9,775	25,815	29,099
Dearborn	2,481	412	1,889	68	5
Decatur	39,369	(D)	9,597	27,554	3
DeKalb	17,712	6,000	6,553	4,662	210
Delaware	6,565	762	(D)	3,893	(D)
Dubois	84,996	6,554	9,235	14,351	54,776
Elkhart	94,375	39,488	17,213	14,976	21,405
Fayette	4,725	(D)	2,329	1,320	4
Floyd	1,080	(D)	(D)	13	(D)
Fountain	5,331	236	2,324	2,647	3
Franklin	10,737	2,641	4,199	3,793	(D)
Fulton	13,895	4,396	4,133	5,240	19
Gibson	10,197	2,138	(D)	5,100	(D)
Grant	9,948	(D)	2,604	3,977	(D)
Greene	24,011	1,306	5,054	10,490	6,854
Hamilton	4,545	740	1,395	1,666	(D)
Hancock	7,906	216	1,094	6,366	28
Harrison	29,234	1,695	5,493	441	21,289
Hendricks	7,104	1,344	(D)	3,160	(D)
Henry	12,272	5,825	4,189	2,044	3
Howard	17,761	1,184	2,739	13,702	44
Huntington	21,035	(D)	2,054	5,009	11,271
Jackson	48,729	4,322	6,721	(D)	(D)

County	Total Animal Sales (000$)	Dairy Sales (000$)	Cattle Sales (000$)	Hog Sales (000$)	Poultry Sales (000$)
Jasper	60,937	29,940	7,863	18,787	4,238
Jay	66,636	4,475	4,433	19,668	37,867
Jefferson	3,808	1,250	2,167	240	(D)
Jennings	20,271	343	(D)	894	(D)
Johnson	15,187	3,563	2,307	9,140	(D)
Knox	13,697	412	3,057	7,497	2,601
Kosciusko	73,659	(D)	14,078	(D)	36,881
LaGrange	66,159	20,066	23,566	7,886	11,159
Lake	2,886	1,041	772	(D)	3
LaPorte	23,675	11,360	8,249	(D)	9
Lawrence	8,241	936	5,152	(D)	(D)
Madison	7,426	332	1,573	5,054	3
Marion	(D)	0	513	(D)	0
Marshall	23,137	13,726	4,018	1,359	3,286
Martin	23,081	1,041	2,935	5,030	13,994
Miami	22,949	4,529	4,058	14,145	2
Monroe	3,452	390	2,816	23	9
Montgomery	24,579	(D)	2,956	20,566	398
Morgan	5,603	(D)	1,451	1,601	4
Newton	71,686	(D)	2,024	(D)	(D)
Noble	26,040	(D)	4,965	8,534	2,975
Ohio	418	0	376	(D)	(D)
Orange	10,276	571	(D)	2,214	(D)
Owen	3,558	532	2,098	637	6
Parke	6,515	2,677	2,761	980	29
Perry	6,075	(D)	2,131	1,853	(D)
Pike	4,527	(D)	(D)	631	3,140
Porter	6,099	(D)	1,840	2,177	7
Posey	7,811	1,702	573	3,084	2,389
Pulaski	30,978	(D)	1,525	9,458	(D)
Putnam	11,174	569	2,414	7,544	69
Randolph	22,288	(D)	2,461	14,045	4,147
Ripley	12,777	1,794	3,561	7,139	(D)
Rush	22,537	3,414	4,769	14,070	3
Scott	2,077	(D)	(D)	(D)	(D)
Shelby	8,229	1,068	1,348	5,576	(D)
Spencer	14,057	(D)	2,538	6,498	3,117
St. Joseph	12,767	3,184	(D)	4,327	(D)

County	Total Animal Sales (000$)	Dairy Sales (000$)	Cattle Sales (000$)	Hog Sales (000$)	Poultry Sales (000$)
Starke	1,941	(D)	734	(D)	(D)
Steuben	7,999	5,427	2,003	467	6
Sullivan	4,717	(D)	1,329	1,937	(D)
Switzerland	1,757	(D)	982	(D)	2
Tippecanoe	17,006	850	1,902	13,819	(D)
Tipton	11,910	(D)	(D)	7,130	(D)
Union	6,894	721	1,535	4,633	(D)
Vanderburgh	1,980	841	261	790	(D)
Vermillion	6,089	0	(D)	(D)	(D)
Vigo	2,492	163	605	1,529	11
Wabash	65,072	(D)	13,933	20,259	(D)
Warren	(D)	0	729	(D)	(D)
Warrick	2,787	1,089	833	802	(D)
Washington	25,451	3,409	5,854	1,983	13,941
Wayne	12,166	3,275	4,260	4,243	(D)
Wells	17,882	(D)	3,280	5,270	(D)
White	45,654	1,558	(D)	(D)	(D)
Whitley	18,654	2,969	8,579	6,303	663
Indiana Total	1,790,411	333,339	324,054	633,112	455,153
County Sales Reported	1,764,101	230,606	301,794	564,393	303,811
Difference	26,310	102,733	22,260	68,719	151,342
Missing Observation	2	27	14	14	39

Appendix C: 2002 Census Inventory for Indiana, by Animal Type, by County

County	Cattle	Milk Cows	Hogs	Layers	Pullets	Broilers	Turkeys	Ducks
Adams	16,005	4,955	128,946	1,002,011	370,272	701	10	30,740
Allen	13,112	2,569	36,768	2,405	156	1,199	24	65
Bartholomew	6,468	1,145	18,755	193	131	64	22	68
Benton	2,472	0	7,223	(D)	(D)	0	0	0
Blackford	1,644	40	35,380	202	(D)	(D)	13	(D)
Boone	4,590	312	39,089	781	540	74	101,565	107
Brown	1,890	(D)	72	300	45	(D)	(D)	23
Carroll	6,224	75	232,653	908	240	88	0	92
Cass	9,498	2,419	60,641	256	39	6	6	55
Clark	10,972	535	2,288	(D)	84	(D)	(D)	(D)
Clay	6,125	1,121	8,603	126	0	0	(D)	(D)
Clinton	1,826	118	182,716	(D)	(D)	(D)	(D)	0
Crawford	7,801	317	85	681	102	47	0	57
Daviess	20,776	3,040	117,389	1,250	191	1,720	632,560	0
Dearborn	8,388	196	804	506	(D)	(D)	0	15
Decatur	15,700	750	154,586	486	(D)	(D)	(D)	118
DeKalb	10,861	2,233	26,276	986	(D)	(D)	(D)	47
Delaware	3,842	358	22,691	526	175	41	46	133
Dubois	26,481	2,879	84,659	1,371,210	839,025	(D)	1,399,776	(D)
Elkhart	49,154	18,183	63,733	31,357	890	637,636	82	382,973
Fayette	6,684	462	8,222	574	196	(D)	0	17
Floyd	2,621	(D)	70	162	(D)	0	0	27
Fountain	6,572	128	11,226	87	0	(D)	(D)	41
Franklin	14,286	1,151	27,802	803	125	147	69	105
Fulton	9,712	1,999	35,002	611	38	87	(D)	44
Gibson	5,045	878	27,463	364	(D)	(D)	(D)	10
Grant	4,571	892	22,111	64,648	(D)	0	(D)	13
Greene	16,708	752	57,353	1,210	286	406	234,864	(D)
Hamilton	3,916	302	10,500	658	212	832	10	35
Hancock	2,899	122	37,082	1,141	(D)	0	(D)	18
Harrison	19,640	857	3,184	(D)	108,208	1,014,231	10	112
Hendricks	5,698	622	19,212	509	267	(D)	(D)	20
Henry	10,412	2,355	11,457	395	(D)	75	(D)	(D)
Howard	3,810	580	85,375	4,533	689	97	(D)	(D)
Huntington	6,152	912	28,394	167,944	(D)	336	0	19
Jackson	15,895	2,312	18,833	(D)	(D)	(D)	(D)	64
Jasper	18,177	10,026	106,738	(D)	(D)	(D)	10	18

County	Cattle	Milk Cows	Hogs	Layers	Pullets	Broilers	Turkeys	Ducks
Jay	11,224	2,203	91,245	2,281,639	678,100	139	208,440	110
Jefferson	9,811	631	(D)	475	133	31	0	18
Jennings	10,250	262	4,646	(D)	(D)	(D)	(D)	248
Johnson	7,401	1,338	73,392	429	(D)	24	(D)	18
Knox	7,831	221	39,287	164	0	(D)	93,000	0
Kosciusko	22,203	3,696	78,684	(D)	(D)	(D)	(D)	383,127
LaGrange	44,320	10,688	27,755	38,201	3,360	639,371	111	181,211
Lake	2,279	488	2,767	272	207	(D)	14	199
LaPorte	16,732	5,165	17,395	605	304	251	112	291
Lawrence	20,794	470	929	494	15	(D)	(D)	129
Madison	4,340	154	26,875	348	320	0	9	18
Marion	759	0	(D)	84	0	(D)	0	0
Marshall	16,038	6,603	9,134	1,091	135	(D)	33	66,092
Martin	8,286	448	21,509	(D)	745	(D)	429,702	(D)
Miami	9,427	(D)	104,039	490	316	328	32	73
Monroe	8,552	126	23	393	106	0	17	65
Montgomery	6,650	45	129,356	1,678	793	2,101	17,914	53
Morgan	5,821	260	6,264	363	80	(D)	(D)	92
Newton	15,963	(D)	54,238	(D)	0	(D)	0	19
Noble	15,160	4,153	39,948	3,178	527	755	16	73,779
Ohio	2,191	3	(D)	254	(D)	0	0	20
Orange	10,327	353	8,916	(D)	(D)	418	(D)	16
Owen	7,605	256	4,274	578	(D)	38	(D)	24
Parke	8,275	1,348	2,414	2,331	(D)	(D)	(D)	10
Perry	10,832	616	11,367	321	(D)	(D)	(D)	31
Pike	3,190	(D)	2,477	84	(D)	10	136,000	6
Porter	4,488	804	10,742	332	(D)	64	(D)	41
Posey	2,850	764	21,229	32	0	0	(D)	0
Pulaski	5,767	2,056	34,384	(D)	(D)	264	16	(D)
Putnam	8,970	213	44,474	1,307	101	164	(D)	220
Randolph	6,324	686	69,440	(D)	85	72	100,611	33
Ripley	12,559	654	37,767	969	65	(D)	(D)	76
Rush	12,042	1,992	77,549	345	(D)	(D)	(D)	0
Scott	3,492	(D)	27,592	153	0	62	(D)	68
Shelby	4,623	598	170	216	431	12	3	145
Spencer	12,780	944	25,471	(D)	83	(D)	80,502	(D)
St. Joseph	5,932	1,715	34,938	(D)	(D)	230	129	94
Starke	1,792	(D)	1,873	899	81	205	(D)	(D)
Steuben	8,751	2,443	2,265	459	167	117	(D)	32

County	Cattle	Milk Cows	Hogs	Layers	Pullets	Broilers	Turkeys	Ducks
Sullivan	4,522	155	11,159	67	(D)	(D)	(D)	(D)
Switzerland	5,560	285	(D)	502	(D)	48	14	48
Tippecanoe	5,640	364	77,493	1,478	1,590	306	24	56
Tipton	1,648	(D)	42,889	(D)	0	0	(D)	(D)
Union	4,559	333	24,511	250	0	0	3	0
Vanderburgh	1,346	380	3,346	132	(D)	0	0	(D)
Vermillion	2,266	0	(D)	185	(D)	0	0	0
Vigo	2,508	111	10,869	1,048	134	14	19	24
Wabash	14,799	1,760	106,819	(D)	(D)	297	(D)	5
Warren	2,940	(D)	(D)	115	(D)	80	(D)	(D)
Warrick	4,654	532	7,351	99	(D)	0	0	12
Washington	21,776	1,824	13,055	102,774	(D)	1,243,366	54,016	75
Wayne	13,268	1,683	22,657	708	(D)	15	(D)	30
Wells	7,852	2,822	27,933	(D)	(D)	120	26	80
White	5,797	603	124,538	(D)	(D)	263	(D)	17
Whitley	9,681	1,475	35,782	(D)	71	188	0	(D)
Indiana Total	862,074	144,792	3,478,570	21,952,110	5,764,843	3,823,936	3,848,054	1,143,160
County Inventory Reported	862,074	130,318	3,386,611	5,103,365	2,009,860	3,547,140	3,489,830	1,121,741
Difference	0	14,474	91,959	16,848,745	3,754,983	276,796	358,224	21,419
Counties with Missing Observations	0	9	6	20	38	30	38	16
% of State Total Inventory Missing	0.0%	10.0%	2.6%	76.8%	65.1%	7.2%	9.3%	1.9%

Appendix D: 2002 Census Inventory for Indiana, by Type of Cattle, by County

County	Cattle on Feed	Beef Cows	Milk Cows	Other Cattle	All Cattle and Calves
Adams	1,875	794	4,955	10,256	16,005
Allen	1,966	1,040	2,569	9,503	13,112
Bartholomew	1,236	1,955	1,145	3,368	6,468
Benton	270	1,290	0	1,182	2,472
Blackford	354	579	40	1,025	1,644
Boone	984	1,952	312	2,326	4,590
Brown	61	(D)	(D)	826	1,890
Carroll	705	1,601	75	4,548	6,224
Cass	1,607	2,473	2,419	4,606	9,498
Clark	877	4,907	535	5,530	10,972
Clay	950	2,005	1,121	2,999	6,125
Clinton	169	801	118	907	1,826
Crawford	365	3,970	317	3,514	7,801
Daviess	5,145	3,517	3,040	14,219	20,776
Dearborn	1,081	4,059	196	4,133	8,388
Decatur	8,689	2,626	750	12,324	15,700
DeKalb	3,076	710	2,233	7,918	10,861
Delaware	903	1,300	358	2,184	3,842
Dubois	6,404	8,800	2,879	14,802	26,481
Elkhart	2,960	1,581	18,183	29,390	49,154
Fayette	673	2,948	462	3,274	6,684
Floyd	39	(D)	(D)	1,096	2,621
Fountain	1,259	2,591	128	3,853	6,572
Franklin	2,984	4,917	1,151	8,218	14,286
Fulton	2,248	1,950	1,999	5,763	9,712
Gibson	815	1,446	878	2,721	5,045
Grant	1,406	798	892	2,881	4,571
Greene	1,925	8,816	752	7,140	16,708
Hamilton	858	1,268	302	2,346	3,916
Hancock	464	1,264	122	1,513	2,899
Harrison	924	9,905	857	8,878	19,640
Hendricks	872	2,047	622	3,029	5,698
Henry	2,621	2,509	2,355	5,548	10,412
Howard	1,995	473	580	2,757	3,810
Huntington	1,346	1,305	912	3,935	6,152

Jackson	4,895	4,104	2,312	9,479	15,895
Jasper	3,315	1,690	10,026	6,461	18,177
Jay	3,166	1,033	2,203	7,988	11,224
Jefferson	1,065	4,993	631	4,187	9,811
Jennings	2,515	3,488	262	6,500	10,250
Johnson	1,810	1,442	1,338	4,621	7,401
Knox	2,694	2,840	221	4,770	7,831
Kosciusko	4,788	2,780	3,696	15,727	22,203
LaGrange	4,109	1,383	10,688	32,249	44,320
Lake	215	555	488	1,236	2,279
LaPorte	3,215	1,675	5,165	9,892	16,732
Lawrence	987	11,247	470	9,077	20,794
Madison	1,049	1,730	154	2,456	4,340
Marion	313	253	0	506	759
Marshall	1,566	1,862	6,603	7,573	16,038
Martin	2,189	3,257	448	4,581	8,286
Miami	1,982	(D)	(D)	5,779	9,427
Monroe	887	4,462	126	3,964	8,552
Montogmery	1,674	2,748	45	3,857	6,650
Morgan	590	2,643	260	2,918	5,821
Newton	308	(D)	(D)	2,485	15,963
Noble	2,691	1,714	4,153	9,293	15,160
Ohio	26	1,328	3	860	2,191
Orange	795	5,336	353	4,638	10,327
Owen	950	3,622	256	3,727	7,605
Parke	1,651	2,723	1,348	4,204	8,275
Perry	562	5,421	616	4,795	10,832
Pike	179	(D)	(D)	1,576	3,190
Porter	821	1,084	804	2,600	4,488
Posey	246	806	764	1,280	2,850
Pulaski	1,036	776	2,056	2,935	5,767
Putnam	1,467	4,361	213	4,396	8,970
Randolph	1,449	1,955	686	3,683	6,324
Ripley	2,216	4,879	654	7,026	12,559
Rush	3,555	2,684	1,992	7,366	12,042
Scott	207	(D)	(D)	1,474	3,492
Shelby	833	1,494	598	2,531	4,623
Spencer	1,645	5,758	944	6,078	12,780
St. Joseph	1,273	876	1,715	3,341	5,932
Starke	671	(D)	(D)	1,264	1,792

Steuben	1,789	880	2,443	5,428	8,751
Sullivan	517	2,392	155	1,975	4,522
Switzerland	262	3,092	285	2,183	5,560
Tippecanoe	1,010	2,394	364	2,882	5,640
Tipton	821	(D)	(D)	1,349	1,648
Union	1,291	1,366	333	2,860	4,559
Vanderburgh	289	207	380	759	1,346
Vermillion	355	962	0	1,304	2,266
Vigo	149	1,349	111	1,048	2,508
Wabash	2,272	910	1,760	12,129	14,799
Warren	350	(D)	(D)	1,281	2,940
Warrick	547	1,584	532	2,538	4,654
Washington	1,756	9,705	1,824	10,247	21,776
Wayne	3,090	3,818	1,683	7,767	13,268
Wells	477	302	2,822	4,728	7,852
White	1,408	1,949	603	3,245	5,797
Whitley	2,865	953	1,475	7,253	9,681
State Total	144,959	230,421	144,792	486,861	862,074
County Inventory Reported	144,959	219,062	130,318	486,861	862,074
Difference	0	11,359	14,474	0	0
Counties with Missing Observations	0.0%	4.9%	10.0%	0.0%	0.0%
% of State Total Inventory Missing	0	9	9	0	0

Appendix E: County Level VTM, 2006-2010

	Model			% Change From:		
County	2006	2008	2010	06 to 08	08 to 10	06 to 10
Adams	1,448,914	1,504,093	1,403,578	3.8%	-6.7%	-3.1%
Allen	262,138	266,561	12,238	1.7%	-95.4%	-95.3%
Bartholomew	4,261	4,261	4,232	0.0%	-0.7%	-0.7%
Benton	274,322	106,620	187,727	-61.1%	76.1%	-31.6%
Blackford	40,213	6,129	6,043	-84.8%	-1.4%	-85.0%
Boone	357,338	6,770	6,672	-98.1%	-1.5%	-98.1%
Brown	0	0	0	NA	NA	NA
Carroll	160,273	72,784	71,798	-54.6%	-1.4%	-55.2%
Cass	329,033	2,071,004	713,326	529.4%	-65.6%	116.8%
Clark	24,754	25,148	25,012	1.6%	-0.5%	1.0%
Clay	243,010	251,976	66,197	3.7%	-73.7%	-72.8%
Clinton	714,874	696,199	689,385	-2.6%	-1.0%	-3.6%
Crawford	0	0	0	NA	NA	NA
Daviess	266,906	339,700	356,067	27.3%	4.8%	33.4%
De Kalb	125,538	98,148	104,488	-21.8%	6.5%	-16.8%
Dearborn	17,119	17,205	20,087	0.5%	16.7%	17.3%
Decatur	191,433	194,896	212,363	1.8%	9.0%	10.9%
Delaware	163,505	177,362	3,976	8.5%	-97.8%	-97.6%
Dubois	311,347	355,816	354,227	14.3%	-0.4%	13.8%
Elkhart	111,065	54,021	53,169	-51.4%	-1.6%	-52.1%
Fayette	96,429	97,386	108,381	1.0%	11.3%	12.4%
Floyd	0	0	0	NA	NA	NA
Fountain	384,530	369,491	399,500	-3.9%	8.1%	3.9%
Franklin	177,818	168,547	196,912	-5.2%	16.8%	10.7%
Fulton	218,803	27,849	27,412	-87.3%	-1.6%	-87.5%
Gibson	454,500	451,919	110,226	-0.6%	-75.6%	-75.7%
Grant	194,243	578,149	428,937	197.6%	-25.8%	120.8%
Greene	194,315	208,842	222,517	7.5%	6.5%	14.5%
Hamilton	1,745	47,046	1,687	2596.7%	-96.4%	-3.3%
Hancock	7,745	6,056	6,019	-21.8%	-0.6%	-22.3%
Harrison	59,963	57,001	52,242	-4.9%	-8.3%	-12.9%
Hendricks	4,709	2,860	2,840	-39.3%	-0.7%	-39.7%
Henry	291,301	287,309	140,416	-1.4%	-51.1%	-51.8%
Howard	171,652	19,169	18,894	-88.8%	-1.4%	-89.0%
Huntington	279,831	267,475	6,898	-4.4%	-97.4%	-97.5%

Jackson	551,682	281,339	281,698	-49.0%	0.1%	-48.9%
Jasper	164,485	1,401,789	388,915	752.2%	-72.3%	136.4%
Jay	141,698	2,780,619	2,432,887	1862.4%	-12.5%	1617.0%
Jefferson	56,833	24,080	23,673	-57.6%	-1.7%	-58.3%
Jennings	128,134	15,400	15,454	-88.0%	0.3%	-87.9%
Johnson	26,212	21,897	21,630	-16.5%	-1.2%	-17.5%
Knox	627,419	657,153	693,258	4.7%	5.5%	10.5%
Kosciusko	503,113	3,031,959	3,038,066	502.6%	0.2%	503.9%
La Grange	149,769	108,700	121,176	-27.4%	11.5%	-19.1%
La Porte	322,182	157,210	195,580	-51.2%	24.4%	-39.3%
Lake	2,319,323	2,543,606	2,403,596	9.7%	-5.5%	3.6%
Lawrence	312,536	320,296	349,879	2.5%	9.2%	11.9%
Madison	399,749	399,667	1,022,757	0.0%	155.9%	155.8%
Marion	2,145,110	1,908,426	1,927,346	-11.0%	1.0%	-10.2%
Marshall	74,144	4,971	10,347	-93.3%	108.1%	-86.0%
Martin	100,823	88,638	80,551	-12.1%	-9.1%	-20.1%
Miami	250,308	31,807	31,335	-87.3%	-1.5%	-87.5%
Monroe	50,073	14,925	2,780	-70.2%	-81.4%	-94.4%
Montgomery	43,725	3,652,745	1,460,687	8253.9%	-60.0%	3240.6%
Morgan	192,993	188,991	207,351	-2.1%	9.7%	7.4%
Newton	367,618	385,474	414,100	4.9%	7.4%	12.6%
Noble	269,656	195,173	219,356	-27.6%	12.4%	-18.7%
Ohio	0	0	0	NA	NA	NA
Orange	105,215	19,964	19,759	-81.0%	-1.0%	-81.2%
Owen	214,186	226,332	240,121	5.7%	6.1%	12.1%
Parke	266,485	220,422	199,974	-17.3%	-9.3%	-25.0%
Perry	43,189	47,029	52,486	8.9%	11.6%	21.5%
Pike	139,748	135,258	143,684	-3.2%	6.2%	2.8%
Porter	51,965	52,924	54,027	1.8%	2.1%	4.0%
Posey	750,265	739,995	5,732,184	-1.4%	674.6%	664.0%
Pulaski	508,389	397,740	47,968	-21.8%	-87.9%	-90.6%
Putnam	225,813	244,561	2,024,256	8.3%	727.7%	796.4%
Randolph	387,469	153,855	1,750,488	-60.3%	1037.8%	351.8%
Ripley	233,588	215,221	251,709	-7.9%	17.0%	7.8%
Rush	323,687	327,008	356,096	1.0%	8.9%	10.0%
Scott	51,958	0	0	-100.0%	-100.0%	-100.0%
Shelby	3,297,606	3,325,789	3,302,680	0.9%	-0.7%	0.2%
Spencer	197,698	199,089	207,684	0.7%	4.3%	5.1%

St. Joseph	2,195,793	1,441,637	1,331,683	-34.3%	-7.6%	-39.4%
Starke	287,946	112,617	253,657	-60.9%	125.2%	-11.9%
Steuben	139,844	141,149	149,964	0.9%	6.2%	7.2%
Sullivan	246,920	269,464	281,126	9.1%	4.3%	13.9%
Switzerland	0	0	0	NA	NA	NA
Tippecanoe	2,881,551	2,773,530	2,731,019	-3.7%	-1.5%	-5.2%
Tipton	196,929	190,121	13,751	-3.5%	-92.8%	-93.0%
Union	79,976	77,733	86,876	-2.8%	11.8%	8.6%
Vanderburgh	81,924	80,693	80,653	-1.5%	0.0%	-1.6%
Vermillion	83,679	106,317	112,388	27.1%	5.7%	34.3%
Vigo	187,659	194,243	207,020	3.5%	6.6%	10.3%
Wabash	390,915	57,632	1,015,336	-85.3%	1661.7%	159.7%
Warren	13,455	11,649	11,480	-13.4%	-1.4%	-14.7%
Warrick	261,429	231,868	71,397	-11.3%	-69.2%	-72.7%
Washington	1,362,577	1,351,082	1,342,370	-0.8%	-0.6%	-1.5%
Wayne	244,403	188,901	41,734	-22.7%	-77.9%	-82.9%
Wells	254,345	262,795	3,899,845	3.3%	1384.0%	1433.3%
White	48,825	47,703	47,072	-2.3%	-1.3%	-3.6%
Whitley	300,361	193,628	221,397	-35.5%	14.3%	-26.3%