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The Effects of Ethanol Production on the U.S. Catfish Sector

Hualu Zheng

THE EFFECTS OF ETHANOL PRODUCTION ON THE U.S. CATFISH SECTOR

By

Hualu Zheng

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By

Hualu Zheng

Approved:

Andrew Muhammad
Associate Professor
Agricultural Economics
(Director of Thesis)

Stan Spurlock
Professor and Graduate
Coordinator of
Agricultural Economics

C. W. Herndon, Jr.
Professor
Agricultural Economics
(Co-Advisor)

Daniel R. Petrolia
Assistant Professor
Agricultural Economics
(Committee Member)

Melissa Mixon
Interim Dean of the College of
Agriculture and Life Science

Name: Hualu Zheng

Date of Degree: August 8, 2009

Institution: Mississippi State University

Major Field: Agriculture (Agricultural Economics)

Major Professor: Dr. Andrew Muhammad

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Candidate for Degree of Master of Science

The overall purpose of this study is to estimate how the rise in grain prices (especially corn prices) induced by ethanol production impacts U.S. catfish industry. Using monthly data from January 1996 to December 2007, an ARDL model and bounds testing procedure were used. The existence of cointegration between the feed price and its regressors and between the farm price and its regressors was found. Results show that the short- and long-run feed price elasticity with respect to corn prices were 0.224 and 0.075, respectively. It was found that energy is more important to catfish feed production than to farm level catfish production, and is more important to processor level production than to farm level production.

Results further showed that catfish farmers will lose net returns because the estimated farm price elasticity with respect to feed prices was smaller than the necessary change that would keep net returns the same.

Key words: catfish, feed, prices, corn, energy, ethanol production, ARDL model

DEDICATION

I would like to dedicate this research to my mother, Lixia Zheng, and my grandfather, Chengqian Zheng.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Agricultural output is influenced by a number of factors, where the supply and demand of these products are directly and/or indirectly determined by these factors. Key factors affecting agricultural commodities include plant and animal diseases, weather, technological improvements, input prices, international supply and demand, as well as the price of related products in production and consumption (Patzek, 2004). Input prices are important factors which critically affect the supply. Feed costs, which are a core part of animal production, play a key role in determining livestock prices. Feed costs represent 50 to 70 percent of livestock production expenses and are a critical component of livestock profitability (Wright et al., 2007).

The increase in corn prices and feed costs has created concerns in the U.S. catfish industry. Corn and soybeans are the primary ingredients in catfish feed. Among all feed ingredients, corn can account for up to 32.1 percent, and soybean meal takes up to 41.6 percent of total feed by volume (Robinson, Li, and Hogue, 2006). Feed costs are the primary expense in catfish production, which account for over 50 percent of the total variable costs. Wells (2007) indicated that market trends and increased corn prices have resulted in catfish feed cost increasing by nearly $30 per ton from 2006 to 2007. Spencer (2008) gave an even greater estimate. He noted that feed that once sold for $250 a ton was selling from $380 to $410 a ton in 2007, an increase of 60 percent.

The increase in feed prices is not only an issue for the catfish industry, but for all animal production. Given the importance of feed to animal production, livestock supply is significantly determined by feed costs, which are mainly composed of the cost of grains, such as corn and soybeans. In 2008, about 45.9 percent of corn produced in the U.S. was used as animal feed for livestock and poultry (Economic Research Service, 2009a). Leibtag (2008) gave it a higher estimate, 55 percent. Considering the importance of feed to livestock production, and given corn's key role in animal feed, corn prices significantly influence livestock prices.

Rosenwald (2007) noted that cattle ranchers paid more for animal feed, and that cattle prices increased with corn prices. For example, from 2006 to 2007, corn prices increased from around $2.00 per bushel to around $4.00 per bushel; during this same period, cattle prices increased from $82.50 per cwt to $91.15 per cwt. Lawrence (2008) stated that for every $1.00 increase in corn price, the carcass price of hogs increased as high as about $18 per pig or $11.30 per cwt, indicating a 5 percent reduction in pork supplies to the packer.

In recent years, the demand for corn has expanded greatly due to increased ethanol production. Although ethanol's share in the overall gasoline market is relatively small, the growth of the industry has been exponential. According to U.S. Department of Energy, from 2000 to 2008, U.S. ethanol production increased from 1,622,334,000 gallons to approximately 8,382,570, 000 gallons, an increase of 416.7 percent. Because corn is the primary ingredient in ethanol production in the U.S., corn prices have significantly increased due to expanded ethanol production. The average corn price increased from $2.24/bushel in 2000 to $4.11/bushel in 2007, an increase of 83.5 percent (Economic Research Service, 2008).

Average crude oil prices were less than $20 per barrel in the 1990s. However, they reached almost $68 in the summer of 2006, and averaged $59 for the year (Westcott, 2007). Crude oil prices rose beyond $140 per barrel in 2008. World demand for oil is expected to continue to expand due to the growth of the global economy. As a result, interest in ethanol as an alternative fuel source has increased dramatically in recently years. According to Renewable Fuels Association 2007 data, the United States had 110 ethanol plants with total annual capacity of 5.4 billion gallons. In addition, there were 73 ethanol plants under construction and many facilities were expanding in the period of 2007-2008.

In order to meet the growing ethanol demand, U.S. corn production has expanded. Laws (2007) noted that ethanol production used approximately 24 percent of the corn harvest in 2007, and production would need about 31 percent of the entire U.S. corn crop in the 2008-2009 period. It was estimated that an additional one billion bushels of corn would be used in ethanol production in 2008-2009, and a billion bushels of corn would require an additional 6.5 million acres of the grain for the 2009-2010 period.

USDA breaks corn usage into three categories: feed/residual, food/seed/industrial, and export. According to ERS, in the 2007-2008 period, 45.9 percent of total U.S. corn production was used to produce livestock feed, 35.2 percent was used for food/seed/industrial uses, and 18.9 percent was exported. Of the 35.2 percent in food/seed/industrial usage, ethanol took up 24.7 percent of total corn use. The majority of U.S. corn is used to feed livestock. However, the percentage of livestock/residual usage has been declining, while more corn was used for ethanol production. Changes in corn usage are shown in Figure 1.1.

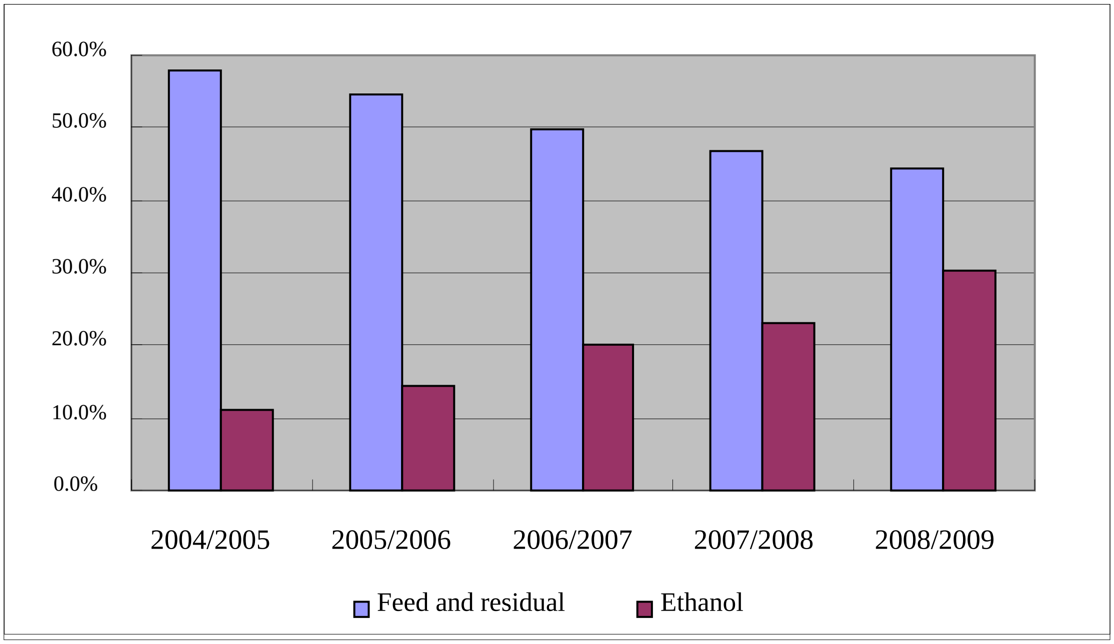

Figure 1.1 Corn Usage: 2004-2009

Source: Agricultural Marketing Resource Center, Iowa State University
Note: 2007-2008 is preliminary, and 2008-2009 is projected.

Figure 1.1 shows U.S corn usage for livestock/residual and ethanol from 2004 to 2009. From 2004/2005 to 2008/2009, the percentage of corn used for livestock declined annually, from 57.8 percent to 44.5 percent, a decrease of 13.3 percent. The percentage of corn used in ethanol production increased from 11.2 percent to 30.2 percent (Figure 1.1).

Regardless of feed formula, corn and soybean meal are always key ingredients in making the least-cost and most nutritious catfish feed, followed by cottonseed meal and wheat middling. Given the importance of corn to catfish feed, there is a strong relationship between catfish feed prices and corn prices, which is shown in Figure 1.2.

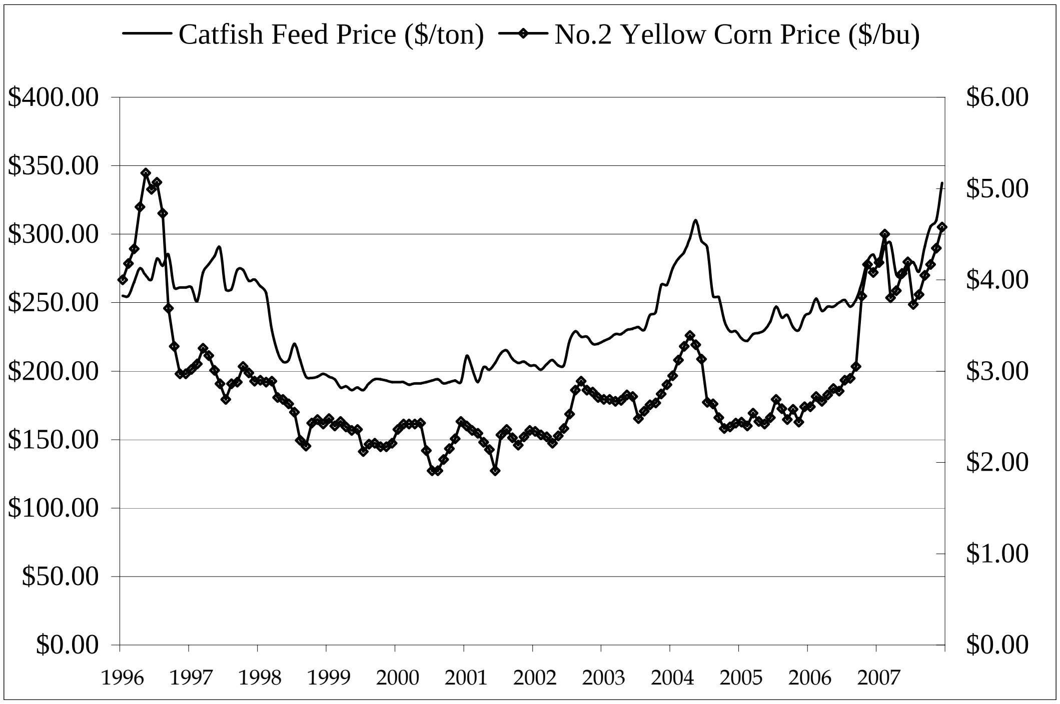

Figure 1.2 Catfish Feed and Corn Prices: 1996-2007

(Source: Hanson and Sites, 2008; and Economic Research Service, 2008)

According to Figure 1.2, corn prices increased from $2.26 per bushel in 2001 to $4.58 at the end of 2007, which a doubling in price. In 2001, the average feed price was $205.75 per ton. Feed prices increased throughout 2006 and 2007 reaching $337.48 per ton in December 2007, an increase of 64.0 percent.

1.1 Objectives

Changes in the equilibrium corn and catfish feed prices have caused economic hardship for catfish producers (Mississippi Agricultural and Forestry Experiment Station, 2007). Increased feed costs and lower farm-level catfish prices have resulted in a decrease of more than 10,000 catfish water surface acres from 2005 to the end of 2007 (Hanson and Sites, 2008). According to Spencer (2008), some catfish farmers emptied their ponds because of those high costs. For example, in 2007, U.S. catfish inventory held in ponds was 409,790,000 lbs, which was 30,135,000 lbs less than the level in 2006 (Hanson and Sites, 2008).

The overall purpose of this study is to estimate how the rise in grain prices (especially corn prices) induced by ethanol production impacts catfish feed prices and catfish prices at the farm level. The research will follow two steps. First, the econometric relationship between grain prices, especially corn and soybean meal prices with catfish feed prices is examined.

Second, the econometric relationship between feed prices and catfish prices at the farm level will be estimated. Short-run and long-run elasticites will be calculated to describe how grain prices impact catfish prices at the farm level and feed prices. Given the relationship between ethanol production and corn prices obtained from other studies, the impact of ethanol production on the U.S. catfish sector will be assessed.

The specific objectives of this study are:

1: Estimate the long-run and short-run relationship between catfish feed prices and the following prices: corn prices, soybean meal prices, cottonseed meal prices, wheat middling prices, and energy prices;

2: Estimate the long-run and short-run relationship between catfish prices at the farm level and the following prices: catfish feed prices, energy prices, and catfish prices at the processor level;

3: Assess the impact of U.S. ethanol production on catfish feed prices and catfish farm prices.

1.2 Outline of Thesis

Chapter 1 is the introduction, which includes the specific problem statement and research objectives. Chapter 2 provides an overview of U.S. catfish production, ethanol production, and energy policy. Chapter 3 is the literature review. Studies that highlight the relationship between feed and animal production are reviewed in this chapter. In addition, issues relating to time series modeling are also reviewed. Chapter 4 is the conceptual framework. Model development of the catfish farm sector is described in this chapter. Chapter 5 focuses on the econometric methods. Chapter 6 reports the empirical results. The conclusion and research implications are given in Chapter 7.

CHAPTER II

BACKGROUND

2.1 U.S. Catfish Industry

Catfish is by far the leading aquaculture industry in the United States. In 2003, commercial catfish production accounted for 46 percent of the value of aquaculture production in the United States (Mississippi State University Extension Service, 2007). The beginnings of the modern catfish industry can be traced back to 1960s. Since the beginning of commercial production in ponds, the growth of the industry has been significant. For instance, in 1970, less than 6 million pounds of catfish were processed. By 1990, over 360 million pounds were processed, which was 60 times higher. By 2003, catfish sales reached 660 million pounds (Crews, 2002).

Mississippi is the leading U.S. producer of catfish. In 2001, Mississippi produced 381 million pounds of farm-raised catfish for processing. This was around 64 percent of the total catfish processed in the United States. Alabama, Arkansas, and Louisiana are also major producers. In 2002, these three states along with Mississippi accounted for more than 95 percent of total pond acreage in the U.S., and more than 95% of catfish sales at the farm level (Dean, Hanson, and Murray, 2003).

The catfish industry has created numerous job opportunities on catfish farms, processing plants and feed mills, providing relatively stable employment in the southern United State for years. According to Mississippi State University Extension Service data, in 2003, the Mississippi catfish industry employed more than 3,000 people on catfish farms, more than 3,600 workers in processing plants, and 330 in feed mills. Total payroll exceeded $102 million, and total industry investment exceeded $600 million.

The U.S. catfish industry has been experiencing challenges. Since production peaked at 661,380,000 lbs in 2003, it dropped to 564,860,407 lbs in 2006, which was a decrease of 14.5 percent (Foreign Agricultural Service, 2007). Low farm-level catfish prices starting in 2003 ($0.58 per pound) caused economic hardship for Mississippi producers, where the number of acres to decrease from 109,000 acres in 2003 to 94,000 acres in 2007, a decrease of 15,000 acres (Streitfeld, 2008).

Figure 2.1 shows U.S. catfish inventory held in ponds from 1998 to 2007. Food-size catfish inventories were 316,347,000 lbs in 1998. Inventories increased

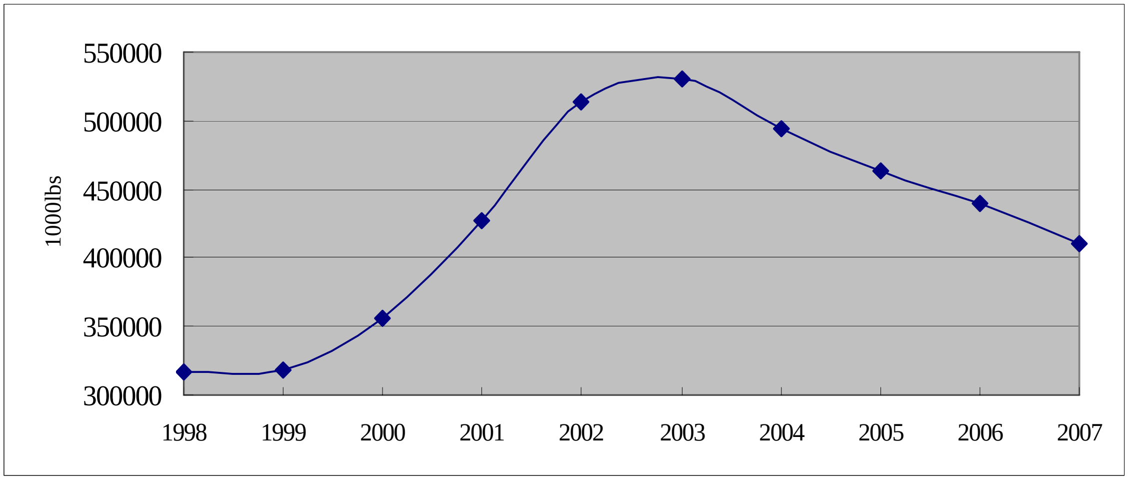

Figure 2.1 U.S. Catfish Inventory Held in Ponds: 1998-2007 (as of January data)

Source: Hanson and Sites, 2008

annually since 1998, and reached a peak of 531,103,000 lbs in 2003, which was an increase of 67.9 percent. Inventories have declined since 2003. In 2007, inventories were 409,790,000 lbs, a decrease of 22.8 percent, when compared to 2003.

Figure 2.2 shows the number of U.S. catfish operations from 1994 to 2007. During this period, U.S. catfish operations decreased from 1,404 in 1994 to 1,023 in 2007. This represented a decrease of about 27.1 percent. The number of operations decreased annually since 2001, except a slight increase in 2005. A larger drop occurred in 2006, which was the largest annual decrease during the 1994-2007 period.

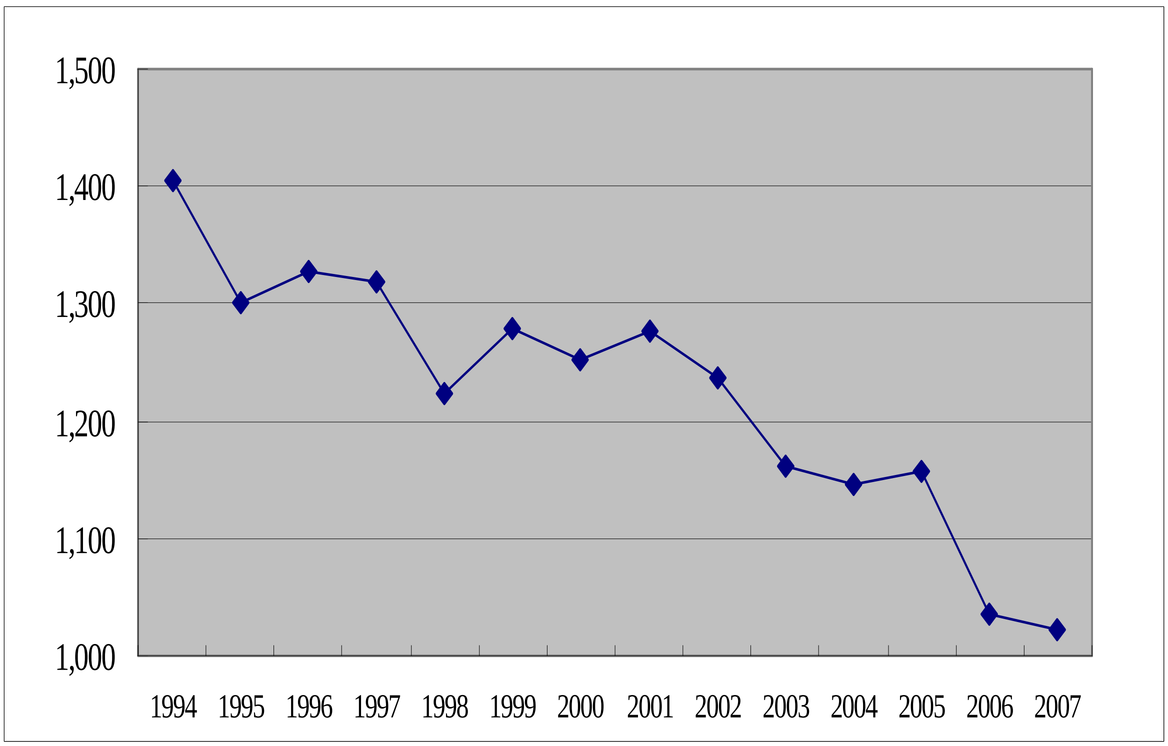

Figure 2.2 Number of U.S. Catfish Operations: 1994-2007 (January data)

Source: Hanson and Sites, 2008

Figure 2.3 shows U.S. food-size catfish sales in pounds and dollars from 1996 to 2006. Catfish sales increased from 506,518,000 lbs in 1996 to 699,310,000 lbs in 2003, an increase of 38.1 percent. However, total sales were 583,580,000 lbs in 2006, which was a decrease of 16.5 percent since 2003. Compared to quantity, values didn't change as much during the same period. Values decreased from $468,815,000 in 2000 to $380,046,000 in 2002, and then it increased to $450,873,000 in 2004. Values maintained around $450 million throughout 2005 and 2006.

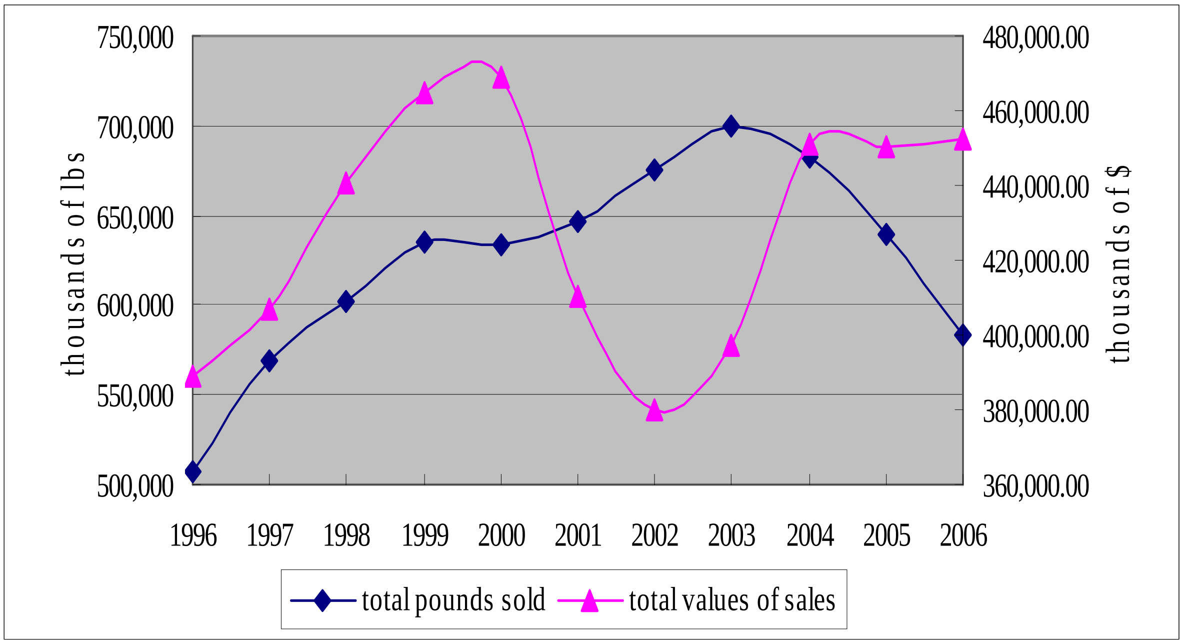

Figure 2.3 Total U.S. Catfish Sales: 1996-2006

Source: Hanson and Sites, 2008

Figure 2.4 shows U.S. catfish farm prices from 1996 to 2007. Farm prices dropped in 2000/2001 and 2001/2002 periods, where the price was $0.75 per pound in 2000, but $0.57 per pound in 2002, a decrease of 24 percent. Farm prices increased since 2003, from $0.58 per pound to $0.80 per pound in 2006, an increase of 37.9 percent.

Farm prices peaked ($0.84 per pound) in early 2007, and then decreased to $0.65 per pound late 2007, a decrease of 22.6 percent.

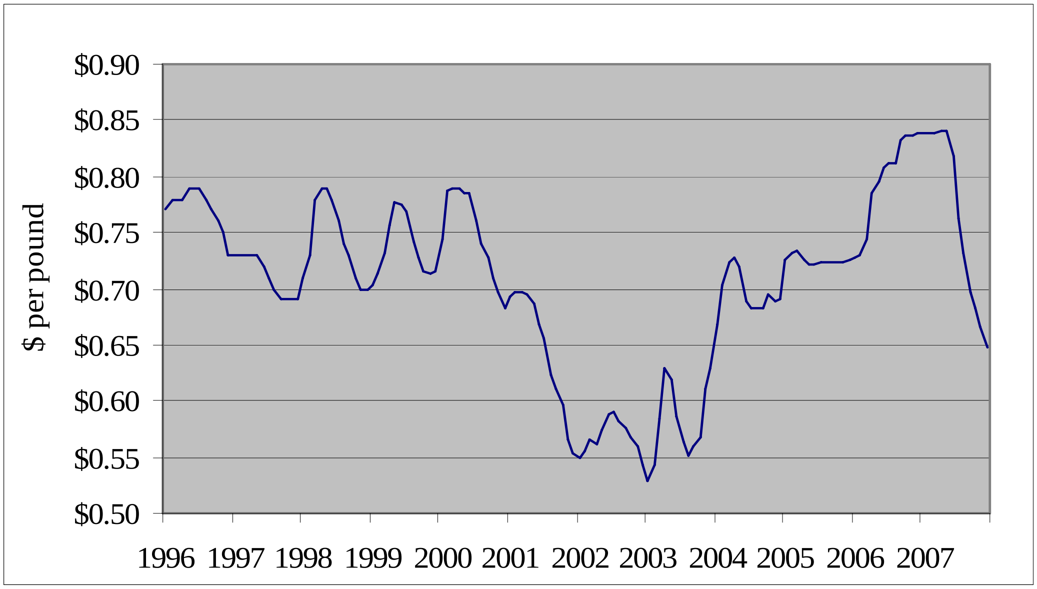

Figure 2.4 U.S. Food-size Catfish Price: 1996-2007

Source: National Agricultural Statistics Service, 2008

2.2 Feed

Corn and soybean meal are primary ingredients in catfish feed production, followed by cottonseed meal and wheat middling. Protein levels of 28 to 32 percent are adequate for feeding catfish (Robinson, Li, and Hogue, 2006). Feed ingredients percentage at various protein levels are given in Table 2.1. Feed with 28 percent protein contains up to 35.4 percent soybean meal and up to 33.6 percent corn. Wheat middling accounts for 20 percent, and cottonseed meal accounts for 10 percent. In 32 percent protein feed, soybean meal takes up to 41.6 percent and corn takes up to 32.1 percent. Wheat middling and cottonseed meal each accounts for 10 percent.

Table 2.1 Feed Ingredients Percentage for Various Feed Proteins

Catfish Feed Ingredients	Food-size Catfish Feed 32% protein	32% protein	28% protein	28% protein
	percentage			
Soybean meal	41.6	47.0	30.1	35.4
Corn Grain	32.1	30.3	33.6	31.9
Cottonseed meal	10.0	10.0	10.0	10.0
Wheat middlings	10.0	10.0	20.0	20.0

Source: Robinson, Li and Hogue, 2006

The price of catfish feed ingredients have significantly increased since 2004. Figure 2.5 shows feed ingredients prices from 1990 to 2008. Corn prices have increased since 2000, where the average price was $2.24 per bushel and rose to $2.83 per bushel in 2004. Corn prices dropped in the 2004/2005 period, but increased significantly since 2006, and rose to $5.50 per bushel in early 2008. When compared to 2007, soybean meal also increased since 2004. The price of soybean meal was $189.29 per ton in 2005; however, prices increased throughout 2006 and 2007 reaching $412.25 per ton in July 2008. Cottonseed meal prices increased from $112.50 per ton in January 2005 to over $335.00 per ton in late 2008. The increase in wheat middling prices was more recent, where prices were $49.20 per ton in May 2006, and increased up to $137.29 per ton at the end of 2007.

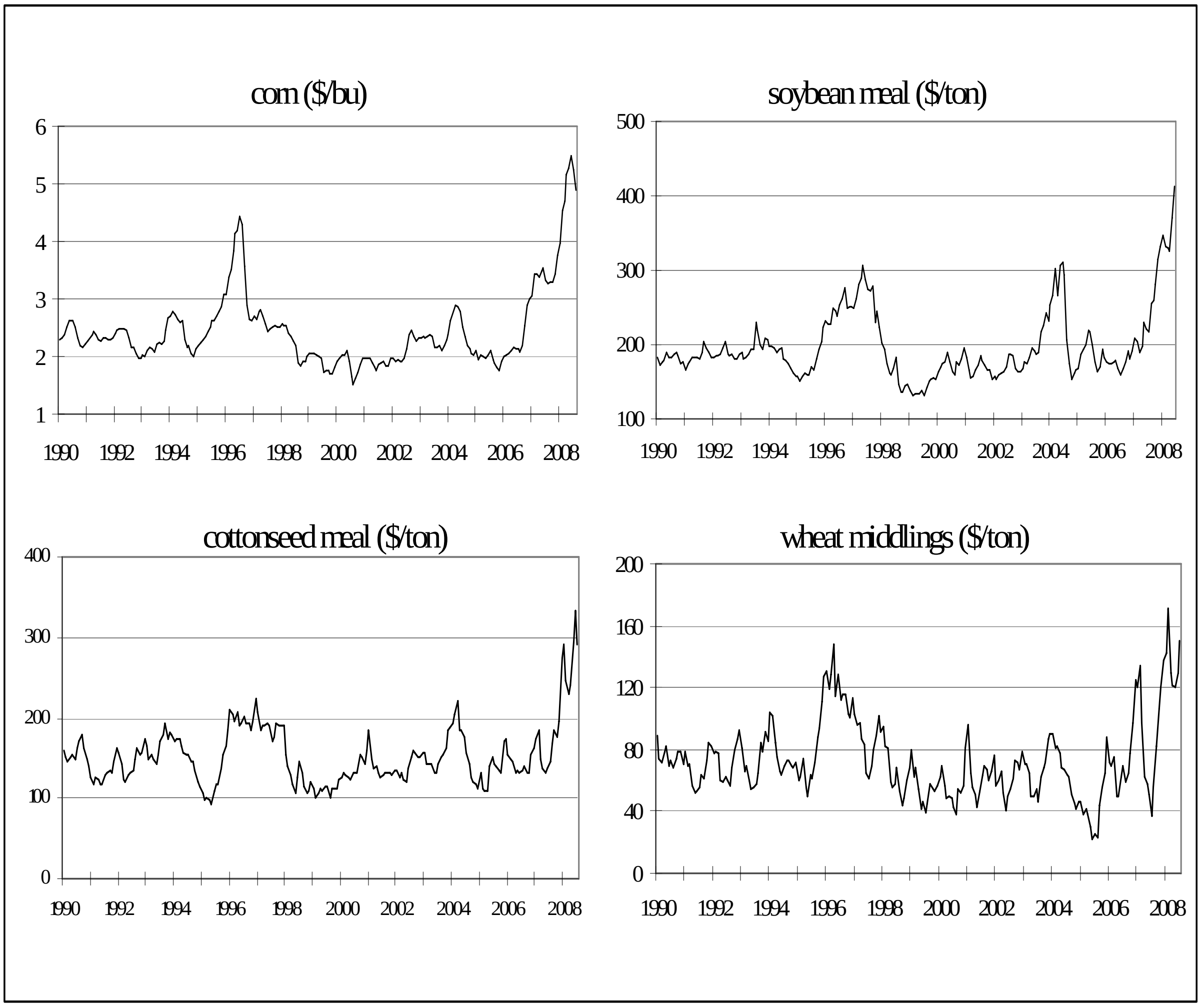

Figure 2.5 Price of Catfish Feed Ingredient: 1990-2008

Source: Economic Research Service, 2009

2.3 U.S Ethanol Production and Energy Policy

The growth of the U.S. ethanol industry has been encouraged by high world oil prices, the banning of Methy1 Tertiary-buty1 Ether (MTBE) as a gasoline oxygenate, the passage of the Renewable Fuel Standard (RFS) of the Energy Policy Act of 2005 (EPACT 2005) (Eidman, 2007), and the Energy Independence And Security Act of 2007.

Other existing federal and state biofuel programs and federal tax laws were also important.

Crude oil prices were less than $20 per barrel in the 1990s, but increased to about $68 per barrel in the summer of 2006 (Westcott, 2007). According to the U.S. Department of Energy, crude oil prices continued to increase to $128.02 per barrel in the summer of 2008, an increase of 88.3 percent when compared to 2006.

To combat growing crude oil prices and related problems, U.S. congress passed EPACT 2005 on July 29th, 2005. The act changed U.S. energy policy by providing tax incentives and loan guarantees for various types of alternative energy production, especially for ethanol production. The act required an increase in the amount of biofuels (usually ethanol) that must be mixed with gasoline in the U.S. The mandated levels are 4 billion gallons by 2006, 6.1 billion gallons by 2009, and 7.5 billion gallons by 2012 (EPACT 2005, Title12, Subtitle C, Section 1303). The "Twenty in Ten" 2007 State of the Union Policy Initiative required an increase in the supply of alternative fuels by setting a mandatory fuels standard which assured a sale of 35 billion gallons of renewable and alternative fuels 2017 (Gonzalez, Sheldon, and Thompson, 2007).

Since 1978, the U.S. government has continuously maintained various national tax incentives to encourage ethanol production and use. Several revisions, additions, modifications, and extensions of the federal ethanol tax incentives have been enacted by Congress since the original implementation. For example, the original policy incentive was enacted in the Energy Tax Act of 1978, which required an exemption of 4 cents per gallon from the federal gasoline excise tax for all 10 percent ethanol/gasoline blends. It also provided 10 percent energy investment tax credit for biomass-ethanol conversion equipment. The Energy Policy Act of 1993 extended ethanol excise tax exemption to 5.7 and 7.7 percent ethanol/ gasoline blends, and established requirements for alternative fuel vehicle purchases by certain vehicle fleets. The Omnibus Budget Reconciliation Act of 1993 and Transportation Efficiency Act of the 21^{st} Century (1998) raised gasoline excise to 18.4 cents per gallon (MacDonald et al., 2004).

Under these policies, fuel blenders can receive tax credits of $0.51 per gallon for gasoline blended with ethanol, which made ethanol more economical to produce (Kruse et al., 2007). Furthermore, alternative fuel vehicles (vehicles that run on a fuel of any combinations of biofuel and "traditional" petroleum fuels, instead of solely petroleum) received a tax reduction of $1.3 billions, which stimulated the consumption of the alternative fuel, and the production of ethanol (EPACT 2005, Title 12, Subtitle D, Section 1343).

Under such situation, ethanol as an alternative fuel source has expanded dramatically for the transportation sector. Figure 2.6 shows U.S. ethanol production and changes in grain used for ethanol from 1997 to 2007. Total U.S. ethanol production was 1.3 billion gallons in 1997, and it increased to 6.5 billion gallons in 2007, a five-fold increase. Significant expansion of ethanol production requires large quantity of grains such as corn and soybeans. In 1997-2007 period, grains used for ethanol production increased from 0.48 billion bushels to 2.3 billion bushels, indicating an increase of 379.2 percent (Figure 2.6).

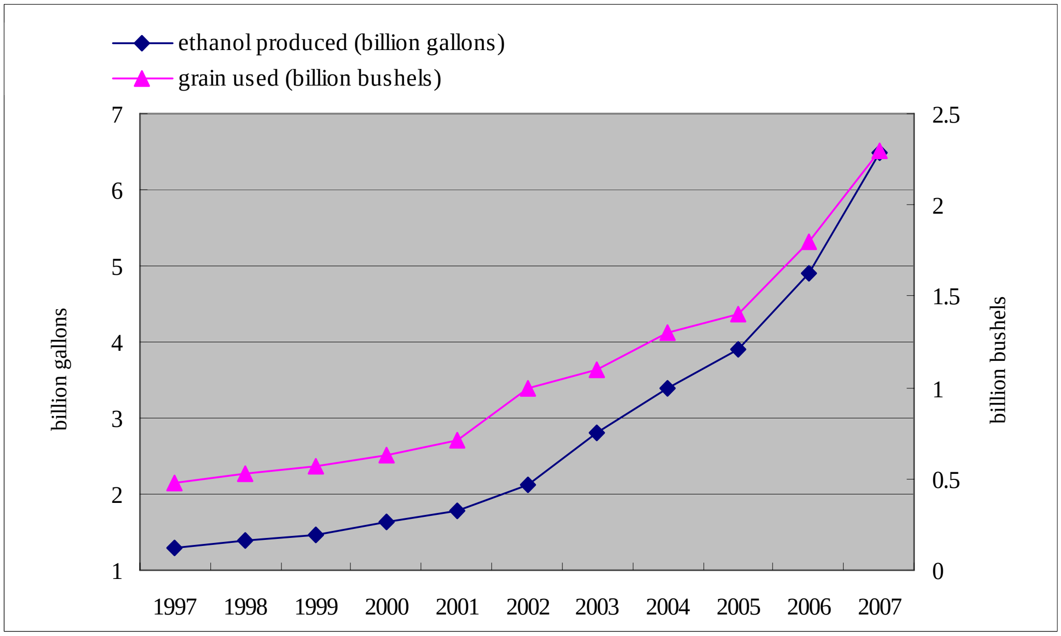

Figure 2.6 Ethanol Production and Grain Usage: 1997-2007

Source: Energy Information Administration, 2008

2.4 Ethanol and Grain Prices

The expansion of ethanol has increased the demand for corn and soybeans, which contributed to the increase in grain prices. Hasing, Zapata, and Parpio (2008) noted that U.S. corn and soybeans prices increased by at least 14 and 21 percent, respectively, in the 2007/2008 period due to ethanol. They further noted that the recent increase in the price of agricultural commodities due to the ethanol expansion varies from 22 percent to 54 percent.

Koo and Taylor (2008) developed a global multi-commodity partial equilibrium econometric simulation model to evaluate the impact of ethanol production on the world corn production. Based on the EPACT 2005, the authors assumed that ethanol production in 2007 was allowed at 6.5 billion gallons, and continued to increase to 7.5 billion gallons by 2012, and maintained the same level through 2016. Using the data from the Economic Research Service for the years 1980 to 2007, they predicted that the corn price would increase from $3.65 per bushel in 2007 to $3.78 in 2008, and $4.40 in 2012, but would be settled at $3.69 in 2016.

According to Taheripour and Tyner (2008), between 2004 and earlier 2008, corn price went from about $2 to $6. The $4 corn price increase can be partitioned into two parts: the price increase due to the U.S. ethanol subsidy and price increase due to the higher crude oil prices. They concluded that about $1 of the increase was due to the U.S. ethanol subsidy and $3 to the crude oil price increase. In other words, of the total increase, 25% was due to U.S. ethanol subsidies and 75% was due to the increase in the price of crude oil (Taheripour and Tyner, 2008).

Park and Fortenbery (2007) developed a system of U.S. corn supply and demand equations focusing on the short-run corn price elasticity associated with U.S. ethanol production. The system was comprised of a single corn supply equation, a set of three corn demand equations, each focused on a specific category of demand: the demand for livestock feed use, the demand for exports use and the demand for food, alcohol and industrial use. Their results showed that corn prices increased as the ethanol production expanded, where a 1% increase in ethanol production caused a 0.16% increase in the corn price in the short run. The authors further noted that if ethanol production increased by 100%, to 10 billion gallons in 2008, then the corn price would increase by 16%, which was about 51 cents per bushel greater relative to the current USDA price forecast.

CHAPTER III

LITERATURE REVIEW

The literature reviewed in this study is divided into two categories. First are studies concerning the effects of corn prices on feed costs and on the livestock sector. A review of these studies will help in understanding what has been done to determine the relationship between corn prices, feed costs, and livestock supply, and how to formulate the structural model of the catfish industry. Second are studies concerning time series issues, such as unit roots, stationarity, cointegration, the error correction model, and the autoregressive distributed lag model.

3.1 Corn Prices, Feed Costs, and the Livestock Sector

Studies focusing on the relationships between corn prices, feed costs, and livestock prices and quantities are reviewed in this section. These studies include Anderson and Trapp (1997); Marsh (2007); Schmit, Verteramo, and Tomek (2008); and Kouka and Engle (1998).

Anderson and Trapp (1997) estimated the relationship between corn prices and feeder cattle prices. In their study, the authors developed the concept of a "corn price multiplier" by qualifying the effect of changes in corn prices on feeder cattle prices. Estimation of the multiplier was accomplished using a partial adjustment model. Under the modified model, the authors concluded that for every $1 increase in corn price, feeder cattle prices will fall by $7.50/cwt. In their model, the independent variables included corn prices, live cattle futures prices, a cattle inventory variable, monthly dummy variables, and the Palmer Drought Severity Index for central Oklahoma (proxy for pasture conditions), which identified the level of soil moisture. Negative values indicated low soil moisture and positive values indicated high soil moisture.

The authors also estimated a break-even feeder cattle price equation using a nonlinear model. The model used the cost and revenue components of the feeder cattle break-even price as explanatory variables. In this model, corn prices served as a key multiplier to the output, which was a determinant of the total costs.

By taking the first derivative of the long-run break-even equation with respect to corn price, the authors obtained a precise estimate of the effects of corn prices on feeder cattle prices. Their results showed that the effect of corn prices on cattle prices was not constant, and varies with the feed conversion ratio (a measure of an animal's efficiency in converting feed mass into increased body weight), in-weight (placement weight) and out-weight (slaughter weight) of the cattle slaughtered. By estimating the modified nonlinear model and using the means of the in-weight and out-weight estimates, and the average feed conversion rate for the period of study, the authors got the impact value of the corn price on the feeder cattle price, which was -8.84. Thus, for every $1 increase in corn prices, feeder cattle prices fall by $8.84/cwt.

In closing, the authors stated that the impact of corn prices on feeder cattle prices was larger than what was commonly reported. They also noted that the corn price multiplier was not constant, but changed in response to changes in cattle weights and the feed conversation rate. Furthermore, the seasonality of the technical factors in the model was also noted to result in noticeable changes to the estimation.

Schmit, Verteramo, and Tomek (2008) estimated the technical relationships between ingredient prices and feed prices for various livestock sectors in the Northeast U.S. Their analysis was based on a cost framework where the price of feed was decomposed into feed components prices and a profit margin.

The model estimated the effects of components prices on feed prices, with omitted costs captured by a trend variable and the residual. One feed component was corn which emphasized the importance of corn price to feed cost. The other component was a combination of other ingredients, including soybean meal, dried distillers grains with solubles (DDGS), and meat and bone meal. They noted that among all ingredient prices contributing to the feed cost, corn prices were the most important driver. The motivation of this study was due to the increase in commodity prices, particularly corn, from 2006 to 2007, which translated into feed price increases in the Northeast of 12.7, 16.8, 17.0 and 18.4 percent, for the hog, layer, broiler, and dairy livestock sectors, respectively.

Feed cost in a given region for a particular livestock sector was defined as the dependent variable. The authors applied three alternative functional forms, linear, semi-log, and inverse, and estimated the equations by Ordinary Least Squares (OLS). They found, however, that a system of seemingly unrelated regressions (SUR) made more statistical sense, and they further performed a chi-square test to support the use of SUR. Under the estimation method of SUR, the semi-log functions had the best statistical fits. Their results also showed that corn, and DDGS were statistically significant for each livestock sector. Soybean meal was statistically significant for the dairy and broilers sectors, while insignificant for hogs and layers.

The authors concluded that corn prices had the highest marginal effect on dairy and broiler feed prices, which were 0.59 and 0.67, respectively. This implied that a dollar per ton increase in the price of corn resulted in a $0.59 ($0.67) per ton increase in the price of dairy (broiler) feed. This was consistent with the fact that dairy and broilers use a relative higher share of corn in their feed rations relative to other livestock industries. The marginal effects of corn prices on feed costs for hogs and layers were 0.50 and 0.45, respectively.

Marsh (2007) jointly estimated farm-level demand and supply equations in feed grains, feeder cattle, slaughter cattle, slaughter hogs, and wholesale broilers, and evaluated the impacts of feed prices, especially corn prices on each sector. Based on the hypothesis of perfect competition and under equilibrium conditions at the market level, he first deduced the structural demand and supply systems for the four livestock-poultry sectors.

Quantity supplied was mainly determined by expected own prices and prices of related competing products. For example, the supply of slaughter cattle was a function of the expected slaughter cattle price and the price of slaughter cows. Supply was also determined by the costs of the major inputs, particular corn. A trend term was used to account for technological change. Quantity demanded at the processer level was determined by the expected own prices, prices of competing products, and labor costs. For example, Slaughter cattle demand was a function of the expected price of slaughter cattle, by-product value of cattle, the index of food market labor costs, and a trend term.

In considering that the quantity of agricultural commodities may be predetermined, demand was estimated as inverse demand, where price was a function of the own quantity produced, the expected cross prices, and input prices.

Because livestock demand and supply exhibit dynamic behavior due to biological growth, technology constraints, and different expectations of sellers and buyers, Marsh (2007) used an autoregressive-distributed lag (ARDL) model to account for the dynamics. Gujarati (2003) notes that a model is an ARDL model if it includes one or more lagged values for the dependent and/or independent variables. The role of lags is to demonstrate long-run impacts of the explanatory variables on the dependent variable and the impact of the dependent variable on itself. The ARDL equations in this model were specified with lags on both endogenous and exogenous variables, where the values of the lag operators were consistent with the livestock production cycle. The model was estimated by three-stage least squares (3SLS), which is a combination of two-stage least squares (2SLS) and SUR (Gujarati, 2003).

Results showed that the inverse demand for feeder calves was affected by the cost of grains in cattle finishing. However, the corn price effect was relatively inelastic, where one percentage increase in the corn price reduced the feeder calf price by 0.21 percent. Slaughter cattle supply was a positive function of output slaughter steer price and a negative function of input prices: corn and feeder calves. A one percent increase in the corn price caused the slaughter cattle supply to decrease by 0.28 percent. The effect of corn price on slaughter hog supply was -0.71, indicating that a one percent increase in the corn price reduced slaughter hog supply by 0.71 percent. Quantity supplied of broilers was also a negative function of corn price, where a one percent increase in the corn price reduced the broiler supply by 0.43 percent.

Kouka and Engle (1998) estimated the supply of the catfish using a multi-stage model at three levels: fry-fingerling, food-size catfish, and wholesale processed catfish. The supply of fry/fingerling was a function of the lagged quantity of fingerlings supplied, the wholesale price of fish, and the price of feed (in terms of corn), representing the major production input. Supply of food-size catfish was a function of the expected wholesale price of fish, the price of feed, and the quantity of fingerlings supplied. The third stage was the wholesale supply of round weight catfish processed. Supply of processed catfish was a function of the quantity of food-size catfish supplied, the wholesale price of fish, and the farm price of fish. Dummy variables accounting for seasonal variations were included at all three stages.

Impacts of changes in feed cost and farm price on catfish supply were analyzed where it was found that a 20 percent increase in feed cost, holding other factors constant, would lead to an 18 percent decrease in fingerling supply and a 2 percent decrease in both the food-size and wholesale supply.

In closing, previous studies show that grain prices, especially corn prices, significantly impact feed prices in various livestock industries. Consequentially, the price of farm products such as cattle, pork, poultry, and catfish are significantly influenced by the changes in corn prices.

3.2 Time Series Modeling

The error correction version of the autoregressive distributed lag (ARDL) model will be used in estimation. Therefore, studies focusing on time series modeling are reviewed in this section, as well as concepts such as unit roots, stationarity, cointegration, the error correction model (ECM), and the ARDL model.

3.2.1 Error Correction Model

Error correction procedures were introduced into the economics literature by Phillips (1954) and by Sargan (1964) (Darnell, 1994). An ECM is a method of combining the cointegrating (long-run) levels relationship between variables of interest and the short-run first difference relationship between variables of interest. The ECM is widely used when both short-run and long-run dynamics are of interest to researchers.

The ECM can be used in estimation only when the dependent and independent variables of interest meet two conditions: (1) each variable must be integrated of order one, denoted $I(1)$, which means they have unit roots; and (2) the variables must be cointegrated, which implies that there is a long-run relationship between the variables (Engle and Granger, 1987).

Unit roots are a process where changes in a variable itself over the previous period can explain all changes in the current period. Consider an autoregressive model as follows:

$$x_t = \rho x_{t-1} + \varepsilon_t \tag{3.1}$$

where ρ is a real number, and ε_t is an error term with mean zero and constant variance.

The time series x_t is a stationary series if $|\rho|$<1. In this case, x_t is integrated of order zero, denoted $I(0)$. If $|\rho|$=1, the time series x_t is nonstationary. In this case, x_t is integrated of order one, denoted $I(1)$. The case of $|\rho|$>1 is usually ruled out. In general, a series is integrated of order *d* if the first difference of that series is integrated of order *d-1*. For *d*=0, x_t is stationary, and for *d*=1, x_t is nonstationary and has a unit root , and $\Delta x_t = x_t - x_{t-1}$ is stationary (Kennedy, 1998).

Two time series x_t and y_t are said to be cointegrated if both x_t and y_t are individually integrated of the same order and there exists a linear combination of the variables which is integrated of a lower order (Darnell, 1994). For instance, if x_t and y_t have a unit root, and a linear combination of the two is stationary, then x_t and y_t are cointegrated.

An ECM involving two variables, x_t and y_t, can be written as

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta x_t + (\beta_1 - 1)(y_{t-1} - \gamma_1 - \gamma_2 x_{t-1}) + \mu_t \tag{3.2}$$

where $(y_{t-1} - \gamma_1 - \gamma_2 x_{t-1})$ is the error correction term reflecting the current error in the long-run equilibrium. x_t and y_t achieve long-run equilibrium when $y_t = \gamma_1 + \gamma_2 x_t$. The key point of the ECM is that a proportion of the disequilibrium from one period is corrected in the next period (Engle and Granger, 1987). The term $(\beta_1 - 1)$ measures the impact of the disequilibrium in the previous period and is expected to be negative. Its absolute value is expected to be less than one (Hallam and Zanoli, 1992). If *y* increases faster than $\gamma_1 + \gamma_2 x$, the error correction term will become bigger and *y* will decrease to the long-run equilibrium.

The ECM has been used frequently in agricultural economics. Hallam and Zanoli (1992) used an ECM to estimate the supply of pig meat in the United Kingdom. They found that there existed a long-run relationship between the size of the breeding herd and retail pig prices and feed prices. Results showed that the short-run elasticities of breeding herd size with respect to pig and feed prices were 0.16 and -0.23, respectively. The long-run elasticities of breeding herd size with respect to pig and feed prices were 1.58 and -2.29, respectively.

Kesavan, Aradhyula, and Johnson (1992) investigated the volatility in farm and retail prices for beef and pork using an ECM. The authors found that retail prices have a positive and significant effect on long-run farm prices of both beef and pork. Their results showed that a one percent increase in retail beef prices leads to a 0.75 percent increase in long-run farm prices, and a one percent increase in retail pork prices leads to a 1.28 percent increase in long-run farm prices.

Reziti and Panagopoulos (2008) employed an ECM to analyze the price transmission mechanism between producers and consumers in Greek agricultural markets. The authors proved the existence of a long-run relationship between agricultural producers and consumers in the food, fruit, and vegetable sectors. They also found that price transmission from producers to consumers was asymmetric in the food market. This implied that in this market, increases in the farm prices were passed though to the retail level more fully than decreases in the farm prices. Price transmission from producers to consumers was symmetric in the fruit market, which implied that increases in the farm prices of fruit were perfectly reflected at the retail level, and so were the decreases in the farm prices. Price transmission was also found to be asymmetric in the vegetable market.

Their results showed that the short-run elasticity of food supply with respect to positive changes in food prices was 0.864, and with respect to negative changes in food prices was 0.917. The long-run elasticity of food supply was 1.02. The short-run elasticity of fruit supply with respect to positive changes in fruit prices was 0.503, and with respect to negative changes in fruit prices was 0.554. The long-run elasticity of fruit supply was 0.93. The short-run elasticity of vegetables supply with respect to positive changes in vegetable prices was 0.506, and with respect to negative changes in vegetable prices was 0.765. However, the difference was not significant. The long-run elasticity of vegetable supply was 0.80.

Shigeto, Hubbard, and Dawson (2008) examined the relationship between farmland prices and rents in Japan from 1995 to 2000. They used the cointegration procedure of Johansen (1992) and the ECM to estimate the model. Their results showed the presence of a cointegrating relationship between farmland prices and rent in Japan.

In the 1980-1981 period, there was a significant break in this long-run relationship, which was due to a fundamental national policy revision in 1970. Under the 1952 law, the maximum level of national farm rent was controlled, but in 1967 the policy was revised and the direct rent control was abolished in 1970. This policy change resulted in a marked increase in rent at the beginning of the 1980s. The authors further noted that this policy revision had a significant impact on the Japanese farmland market in the long-run.

Karagiannis, Katranidis, and Velentzas (2005) estimated a dynamic model of meat demand in Greece using an ECM. They used Greek consumption data over the 1958-1993 period. In the short-run, beef was found to have elastic demand; pork was almost unitary elastic, whereas mutton-lamb, chicken, and sausages had inelastic demands. In the long-run, the beef and pork demand elasticity was elastic, whereas mutton-lamb, chicken, and sausages still had inelastic demand.

Mohanty, Peterson, and Smith (2005) examined the relationship between U.S. and Canadian wheat prices using cointegration methods and the ECM. Their results showed that the Canadian market was largely insulated from influences flowing directly from the United States, while U.S. markets were not insulated from Canadian influences. They further noted that Canada was the price leader in the durum and hard spring wheat markets, and U.S. policies aimed at supporting domestic prices were not effective in the long-run.

3.2.2 Autoregressive Distributed Lag Model and Bounds Testing Procedure

Pesaran, Shin, and Smith (2001) derived an alternative cointegration procedure known as the error correction version of the autoregressive distributed lag (ARDL) model and bounds testing procedure. This procedure allows for testing the existence of long-run relationships between variables of interest, which can be applied to the time series data whether the variables are purely $I(0)$, purely $I(1)$, or a combination of the two. With this approach, the short-run and long-run relationships among series of interest are captured simultaneously while pre-testing for unit roots is not needed.

Compared to the ECM, the ARDL model has certain econometric advantages. First, the ECM requires pretesting for unit roots. The existence of unit roots depends on the testing approach chosen. It is not uncommon for one test to indicate no unit roots while another test indicates the presence of unit roots. For instance, using the

Augmented-Dickey-Fuller approach, one may conclude that unit roots are present. However, if the Phillips-Perron test is applied, one may conclude that unit roots are absent (Pahlavani, Wilson, and Worthington, 2005). This is not the case with the ARDL model. The ARDL modal does not require pretesting for unit roots. Second, to determine the cointegration relationship between time series, the ARDL model is more statistically significant in small samples, while the Johansen co-integration approach requires a large sample for validity (Ghatak and Siddiki, 2001).

To use the ARDL model, there must exist a long-run relationship between the variables. The long-run relationship between the variables can be represented as follows:

$$\ln y_t = \alpha + \beta_1 \ln x_{1t} + \beta_2 \ln x_{2t} + \beta_3 \ln x_{3t} + \varepsilon_t \tag{3.3}$$

Given the long-run relationship, the ARDL model can be written as follows:

$$\Delta \ln y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta \ln y_{t-i} + \sum_{i=0}^{n} \phi_{1i} \Delta \ln x_{1t-i} + \sum_{i=0}^{p} \phi_{2i} \Delta \ln x_{2t-i} \tag{3.4}$$

$$+ \sum_{i=0}^{q} \phi_{3i} \Delta \ln x_{3t-i} + \lambda_0 \ln y_{t-1} + \lambda_1 \ln x_{1t-1} + \lambda_2 \ln x_{2t-1} + \lambda_3 \ln x_{3t-1} + \mu_t \, .$$

Δ is the difference operator where for *y* and any *x*, $\Delta \ln y_t = \ln y_t - \ln y_{t-1}$ and $\Delta \ln x_t = \ln x_t - \ln x_{t-1}$. *m, n, p,* and *q* are the lag orders, and μ_t is the error which is assumed serially uncorrelated. ϕ represents the short-run dynamics between the dependent and independent variables, and λ gives the long-run relationships between the dependent and independent variables.

Before testing for cointegration, the optimal lag orders *m, n, p,* and *q* must be determined first. With the ARDL model, cointegration tests are sensitive to the number of lags imposed (Bahmani, 2008). Furthermore, it is important to choose large enough lags to mitigate serial correlation and small enough lags to avoid over parameterization (Baek and Koo, 2007). The Akaike Information Criterion (AIC) or the Schwarz Bayesian Criterion (SBC) is usually used to determine the appropriate lag orders.

Once the lag orders are determined, the following hypotheses should be tested for the existence of cointegration:

$$H_0\text{: } \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = 0 . \quad (3.5)$$

If H_0 holds true, then the variables are not cointegrated. The F-statistic for the above restriction does not follow the typical F distribution. Pesaran, Shin, and Smith (2001) give the critical values for this test where they derived upper bound critical values when all variables are $I(1)$ and lower bound critical values when all the variables are $I(0)$. The critical values are derived for significance levels of 0.10, 0.05, 0.025, and 0.010; and for cases when the intercept and a trend term are not present, when both are present but restricted, and unrestricted. The variables are cointegrated when the F-statistic for equation (3.5) exceeds the upper bound critical value given in Pesaran, Shin, and Smith (2001). Once the existence of cointegration is proven, the long-run relationship (3.3, and the ARDL model (3.4) can be estimated by Ordinary Least Squares..

The ARDL model and bounds testing approach have been widely used in time series estimation. Using the ARDL bounds testing approach, Baek and Koo (2007) examined the short-run and long-run relationship between the U.S. agricultural trade balance and U.S. real income, foreign income, and real exchange rates.

Their results suggested that in the long-run, the U.S. agricultural trade balance, exchange rates, real income, and foreign income were cointegrated. It was found that the income and money supply in both the United States and in trading partner countries had significant impact on U.S. agricultural trade in both the short-run and long-run. For instance, in the long-run, a one percent increase in the exchange rate, foreign income, and the foreign money supply increased the trade balance by 0.43, 0.17, and 0.15 percent, respectively, and a one percent increase in U.S. income and money supply decreased the trade balance by 4.14 and 0.76 percent, respectively.

Bahmani (2008) estimated the relationship between the money demand, income, interest rates, inflation rates, and nominal exchange rates in Middle Eastern countries, and tested the stability of the money demand in those countries. Because some variables in his model were stationary, and others were not, the ARDL model was used in the estimation.

Results showed that there was a long-run relationship between money demand and the independent variables. In the long-run, a one percent increase in the inflation rate and the exchange rate led to a 0.22 and 1.03 percent increase in Bahrain's money demand, respectively, a 22.1 and 1.9 percent decrease in Egypt's money demand, respectively, a 3.49 and 0.188 percent decrease in Jordan's money demand, respectively, and a 9.84 and 0.884 percent decrease in Kuwait's money demand, respectively.

Oskooee and Ng (2002) examined long-run money demand (M2) in Hong Kong using the ARDL bounds testing procedure. The authors found that there was a long-run relationship between money demand in Hong Kong, real income, nominal interest rates, foreign interest rates, and foreign exchange rates. Their results showed that the long-run elasticities of money demand in Hong Kong with respect to real income, foreign interest rates, foreign exchange rates, and nominal interest rates were 1.73, 0.07, 2.26, and -0.04, respectively.

Vita and Abbott (2002) estimated the long-run relationship between savings and investment in the U.S. using the ARDL bounds testing procedure. They used data from 1946 to 2001, and found that the U.S. saving and investment rates were cointegrated. Results indicated that the long-run elasticities of U.S gross domestic investment with respect to U.S gross national saving was 0.927 in the 1946-1971 period, 0.201 in the 1971-1987 period, respectively. The long-run elasticity for the entire data period (1946-2001) was 0.572.

Atkins and Coe (2002) investigated the existence of the Fisher Effect in Canada and U.S. using the ARDL bounds testing procedure. The Fisher Effect is when the nominal interest rate changes one-for-one with the expected inflation rate. The authors found that there was a long-run relationship between nominal interest rates and the inflation rate in both Canada and the U.S. They proved the existence of the Fisher Effect in both countries. However, the authors found that if interest income is taxed, the Fisher Effect would still hold in the U.S., but not in Canada.

Pahlavani, Wilson, and Worthington (2005) estimated the short-run and long-run relationship between GDP, oil and nonoil exports, real capital, real imports, and human capital in Iraq using the ARDL bounds testing procedure. They estimated two models where oil and nonoil exports were combined as a single variable in one model (model 1), and treated as separate variables in the other (model 2). cointegration was found in both models.

Their results showed that the long-run elasticities of GDP with respect to human capital were 0.018 and 0.02 for model 1 and model 2, respectively. The long-run elasticity of GDP with respect to total exports was 0.39 for model 1. The long-run elasticities of GDP with respect to oil and nonoil exports were 0.37 and 0.036 for model 2, respectively. The long-run elasticity of GDP with respect to real imports were 0.08 and 0.13 for model 1 and model 2, respectively.

CHAPTER IV

CONCEPTUAL FRAMEWORK

4.1 Supply and Demand Analysis of the Catfish Farm Sector

Two markets are considered in this study: the catfish feed market and the catfish market at the farm level. The supply and demand curves for these two markets are shown in Figure 4.1. P_{feed} and Q_{feed} are the price and quantity of catfish feed, respectively. P_f and Q_f are the price and quantity of catfish at the farm level, respectively.

Recently, corn prices have risen because of increasing demand for ethanol where corn is a primary input. Taheripour and Tyner (2008) note that of the $4 corn price increase between 2004 and early 2008, about $1 was due to U.S. ethanol subsidies, and $3 was due to the increase in the crude oil prices. Because corn is a primary ingredient in catfish feed, higher corn prices cause catfish feed supply to decrease, which is shown by a leftward shift in the catfish feed supply curve from S_{feed}^0 to S_{feed}^1 in Figure 4.1(a). The decrease in supply causes the equilibrium feed price to increase from P_{feed}^0 to P_{feed}^1, and the equilibrium feed quantity to decrease from Q_{feed}^0 to Q_{feed}^1.

Feed costs account for over 50 percent of the total variable cost in catfish production, and thus catfish supply should be greatly affected by changes in feed prices. An increase in the price of catfish feed will decrease the catfish supply at the farm level, which is shown by a leftward shift in the farm supply curve from S_f^0 to S_f^1 in

Figure 4.1(b). The equilibrium catfish price at the farm level increases from P_f^0 to P_f^1 and the equilibrium farm quantity decreases from Q_f^0 to Q_f^1.

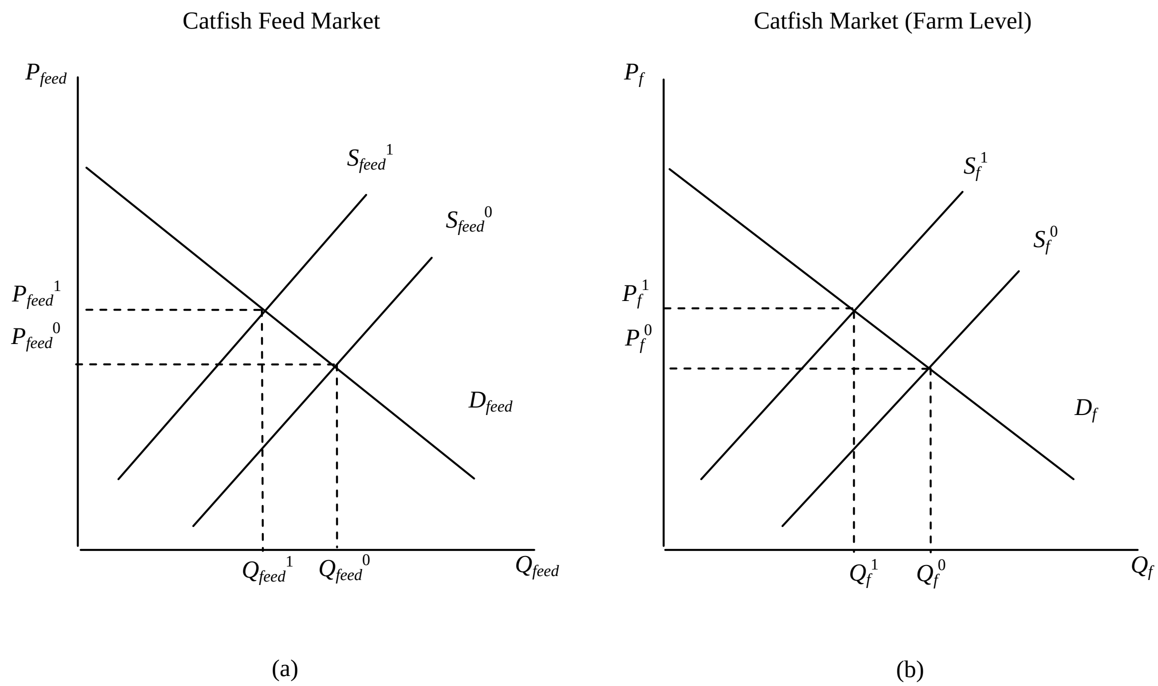

Figure 4.1 The Supply and Demand of Catfish

4.2 Model of the Catfish Feed and Farm Sectors

General equations of the supply and demand for catfish feed are as follows:

Feed Supply: $Q_{feed}^s = Q(P_{feed}, X_1^s, X_2^s, ..., X_n^s)$ (4.1)

Feed Demand: $Q_{feed}^d = Q(P_{feed}, X_1^d, X_2^d, ..., X_n^d)$ (4.2)

Equilibrium Condition: $Q_{feed}^s = Q_{feed}^d = Q_{feed}$ (4.3)

Feed supply is represented by equation (4.1) where the quantity of feed supplied is a function of the price of feed (P_{feed}) and other factors (X^s). X^s are feed supply shifters which could include input prices and measures of technological change. The price of corn, soybean, cottonseed meal, and wheat middlings can be included as input prices because they are the main ingredients in catfish feed. Energy prices can be included to account for the cost of transportation and equipment operation in feed production. Input prices should be supply decreasing.

Feed demand is represented by equation (4.2) where the quantity of feed demanded is a function of the feed price (P_{feed}), and relevant factors (X^d) that could impact the demand. X^d could include the expected price of catfish and input prices at the farm level. The expected catfish price at the farm level should be demand increasing because if catfish farmers expect to receive higher prices, they will demand more feed. The price of inputs used by catfish farmers should be demand decreasing because if catfish farmers face higher input prices, they will demand less feed to produce catfish.

General equations of the supply and demand for catfish at the farm level are as follows:

Catfish Supply: $Q_f^s = Q(P_f, Z_1^s, Z_2^s, ..., Z_n^s)$ (4.4)

Catfish Demand: $Q_f^d = Q(P_f, Z_1^d, Z_2^d, ..., Z_n^d)$ (4.5)

Equilibrium Condition: $Q_f^s = Q_f^d = Q_f$ (4.6)

Catfish supply at the farm level is represented by equation (4.4). The quantity of catfish supplied is a function of the farm level price of catfish (P_f) and other factors that affect catfish farm supply which are represented by Z^s. Z^s could include feed prices, other input prices, and measures of technological change in catfish production. Technological change should be supply increasing and feed and other input prices should be supply decreasing.

Catfish demand at the farm level is represented by equation (4.5) where the quantity of catfish demanded is a function of the catfish price (P_f) and the relevant factors that could determine the demand (Z^d). Z^d could include input prices and the price of catfish at the processor level. Catfish prices at the processor level should be demand increasing because processors want to sell more catfish if they can receive a higher price, and will buy more catfish from farmers. Prices of inputs used by processors should be demand decreasing because if input prices increase, processors will demand less catfish from farmers.

Given the equilibrium conditions (4.3) and (4.6), reduced form equations for the catfish feed price and farm price can be defined as:

$$P_{feed} = P(X_1^s, X_2^s, ..., X_n^s, X_1^d, X_2^d, ..., X_n^d) \quad (4.7)$$

$$P_f = P(Z_1^s, Z_2^s, ..., Z_n^s, Z_1^d, Z_2^d, ..., Z_n^d) \quad (4.8)$$

For any X_i^s that is supply increasing (decreasing), the result is a negative (positive) effect on feed prices. For instance, if corn prices increase, feed producers face a higher cost to produce feed, and they will buy less corn. As a result, feed supply will decrease and the feed price will increase. For any X_i^d that is demand increasing (decreasing), the result is a positive (negative) effect on feed prices. For instance, if farmers can receive a higher farm price, their demand for feed will increase. As a result, feed prices will increase.

For farm prices (P_f), any Z_i^s that is supply increasing (decreasing), the result is a negative (positive) effect on catfish prices at the farm level. For instance, if feed prices increase, catfish farmers face higher cost, and they will purchase less feed. Consequentially, the supply of catfish at the farm level will decrease, and the farm price will increase. For any Z_i^d that is demand increasing (decreasing), the result is a positive (negative) effect on catfish prices at the farm level. For instance, when catfish processors receive higher prices, they will demand more catfish at the farm level. As a result, farm prices will increase.

4.3 The Effects of Energy and Ethanol

Energy prices affect catfish in two ways. First, an increase in energy prices will lead to an increase in catfish feed prices because energy is used to produce catfish feed (supply effect). Second, energy and catfish feed are complements in catfish production. Higher energy prices will cause catfish farmers to produce less catfish and demand less feed, and the feed price will fall (demand effect). In this instance, the impact of energy price on feed price is ambiguous. An increase in energy prices will cause feed prices to increase if the supply effect is larger than the demand effect.

A reduced form price elasticity can be expressed as follows:

$$\eta_{X_i} = \frac{\%\Delta P}{\%\Delta X_i} = \frac{\Delta P}{\Delta X_i}\frac{X_i}{P}$$

This equation measures percentage changes in P given percentage changes in X_i. Let X_i^s represent energy prices for feed suppliers and X_i^d represent energy prices for catfish farmers. The feed price elasticity with respect to energy prices can be written as follows:

$$\eta_{X_i} = \frac{\%\Delta P_{feed}}{\%\Delta X_i} = \frac{\%\Delta P_{feed}}{\%\Delta X_i^s} + \frac{\%\Delta P_{feed}}{\%\Delta X_i^d} \tag{4.9}$$

$$= \frac{\Delta P_{feed}}{\Delta X_i^s}\frac{X_i^s}{P_{feed}} + \frac{\Delta P_{feed}}{\Delta X_i^d}\frac{X_i^d}{P_{feed}} = (\overset{(+)}{\frac{\Delta P_{feed}}{\Delta X_i^s}} + \overset{(-)}{\frac{\Delta P_{feed}}{\Delta X_i^d}})\frac{X_i}{P_{feed}}$$

The last term in (4.9) assumes that feed producers and catfish farmers face the same energy prices. Equation (4.9) can be positive or negative depending on the magnitudes of the supply and demand effects.

The impact of energy prices on the catfish farm market is also uncertain. First, an increase in energy prices will lead to higher farm prices because farmers will decrease supply with higher input cost (supply effect). Second, higher energy prices will cause processors to demand less catfish from farmers, resulting in a decrease in catfish prices at the farm level (demand effect). As a result, the impact of energy prices on catfish farm prices is uncertain.

The catfish production cycle is usually 18 to 24 months (Posadas, 2000). Given this production lag, current farm supply is not a function of current feed prices, but a function of past feed prices. It takes time for feed prices to have an impact on farm prices. Let the short-run be defined as the time period in which farm prices are not affected by current feed prices. Therefore, feed price(s) can be taken as a constant in the short-run.

Let Z_i^s represent energy prices for catfish farmers and Z_i^d represent energy prices for catfish processors. The short-run farm price elasticity with respect to energy prices can be written as follows:

$$\gamma_{Z_i}^{sr} = \frac{\%\Delta P_f}{\%\Delta Z_i} = \frac{\%\Delta P_f}{\%\Delta Z_i^s} + \frac{\%\Delta P_f}{\%\Delta Z_i^d} = \frac{\Delta P_f}{\Delta Z_i^s}\frac{Z_i^s}{P_f} + \frac{\Delta P_f}{\Delta Z_i^d}\frac{Z_i^d}{P_f} = (\overset{(+)}{\frac{\Delta P_f}{\Delta Z_i^s}} + \overset{(-)}{\frac{\Delta P_f}{\Delta Z_i^d}})\frac{Z_i}{P_f} \tag{4.10}$$

The last term in equation (4.10) assumes that catfish farmers and processors face the same energy prices. Equation (4.10) can be positive or negative depending on the magnitudes of the supply and demand effects.

In the long-run, the impact of energy prices on feed prices must be considered. In this case, farm prices are directly affected by energy prices, and indirectly affected by energy prices through feed prices. The long-run farm price elasticity with respect to energy prices can be written as follows:

$$\gamma_{Z_i}^{lr} = \frac{\%\Delta P_f}{\%\Delta P_{feed}}\eta_{X_i} + \frac{\%\Delta P_f}{\%\Delta Z_i} = \frac{\%\Delta P_f}{\%\Delta P_{feed}}(\frac{\%\Delta P_{feed}}{\%\Delta X_i^s} + \frac{\%\Delta P_{feed}}{\%\Delta X_i^d}) + \frac{\%\Delta P_f}{\%\Delta Z_i^s} + \frac{\%\Delta P_f}{\%\Delta Z_i^d} \qquad (4.11)$$

$$= \frac{\Delta P_f}{\Delta P_{feed}}\frac{P_{feed}}{P_f}[(\overset{(+)}{\frac{\Delta P_{feed}}{\Delta X_i^s}} + \overset{(-)}{\frac{\Delta P_{feed}}{\Delta X_i^d}})\frac{X_i}{P_{feed}}] + (\overset{(+)}{\frac{\Delta P_f}{\Delta Z_i^s}} + \overset{(-)}{\frac{\Delta P_f}{\Delta Z_i^d}})\frac{Z_i}{P_f}$$

The effects of U.S. ethanol production on catfish feed and farm prices are also derived in terms of elasticities. Let X_j^s denote corn prices, and *ethanol* denote ethanol production. The feed price elasticity and catfish farm price elasticity with respect to ethanol production can be written as follows:

$$\eta_{ethanol} = \frac{\%\Delta P_{feed}}{\%\Delta ethanol} = \frac{\%\Delta P_{feed}}{\%\Delta X_j^s}\frac{\%\Delta X_j^s}{\%\Delta ethanol} \qquad (4.12)$$

$$= \frac{\Delta P_{feed}}{\Delta X_j^s}\frac{X_j^s}{P_{feed}}\frac{\Delta X_j^s}{\Delta ethanol}\frac{ethanol}{X_j^s}$$

$$\gamma_{ethanol} = \frac{\%\Delta P_f}{\%\Delta ethanol} = \frac{\%\Delta P_f}{\%\Delta P_{feed}}\frac{\%\Delta P_{feed}}{\%\Delta ethanol} \qquad (4.13)$$

$$= (\frac{\Delta P_f}{\Delta P_{feed}}\frac{P_{feed}}{P_f})(\frac{\Delta P_{feed}}{\Delta X_j^s}\frac{X_j^s}{P_{feed}})(\frac{\Delta X_j^s}{\Delta ethanol}\frac{ethanol}{X_j^s})$$

Equations (4.12) and (4.13) give the percentage changes in catfish feed and farm prices caused by percentage changes in the ethanol production, respectively. Since the feed price is fixed in the short-run, equation (4.13) is a long-run effect.

CHAPTER V

EMPIRICAL MODEL

5.1 Econometric Model of U.S. Catfish Industry

Equations (5.1) to (5.4) are the supply and demand equations for the catfish feed and farm markets. They are in log-linear form. Variable descriptions are given in Table 5.1.

Table 5.1 Variable Symbols and Descriptions

Symbol	Description	Unit of Measure
QFD^s	Quantity of supply of catfish feed	Tons
QFD^d	Quantity of demand of catfish feed	Tons
QF^s	Quantity of supply of catfish at the farm level	Pounds (lb)
QF^d	Quantity of demand of catfish at the farm level	Pounds (lb)
PFD	Catfish feed price	$/ton
PF	Catfish farm price	$/lb
PF^e	Expected catfish farm price	$/lb
PP	Catfish price at the processor level	$/lb
PCO	No.2 yellow corn price	$/bushel
PSO	49 percent protein soybean meal price	$/ton
PCT	Cottonseed meal price	$/ton
PWH	Wheat middling price	$/ton
PE	Energy price	Index (No. 2 diesel fuel price)

$$\ln QFD_t^s = a_0 + a_1 \ln PFD_t + a_2 \ln PCO_t + a_3 \ln PSO_t + a_4 \ln PCT_t \quad (5.1)$$

$$+ a_5 \ln PWH_t + a_6 \ln PE_t + \varepsilon_t^s$$

$$\ln QFD_t^d = b_0 + b_1 \ln PFD_t + b_2 \ln PF_t^e + b_3 \ln PE_t + \varepsilon_t^d \quad (5.2)$$

Feed supply (5.1) is a function of feed price (*PFD*), feed ingredient prices: corn (*PCO*), soybean meal (*PSO*), cottonseed meal (*PCT*), and wheat middling (*PCT*), and the price of energy (*PE*). Feed demand (5.2) is a function of feed price (*PFD*), expected catfish price at the farm level (PF^e), and the price of energy (*PE*).

$$\ln QF_t^s = c_0 + c_1 \ln PF_t + c_2 \ln PFD_{t-18} + c_3 \ln PE_t + \mu_t^s \quad (5.3)$$

$$\ln QF_t^d = d_0 + d_1 \ln PF_t + d_2 \ln PP_t + d_3 \ln PE_t + \mu_t^d \quad (5.4)$$

Catfish supply at the farm level (5.3) is a function of the farm price (*PF*), the energy price (*PE*) and the feed price (*PFD*). Since the catfish production cycle is from 18 to 24 months, the feed price is lagged 18 months. Catfish demand at the farm level (5.4) is a function of the farm price (*PF*), catfish prices at the processor level (*PP*), and the price of energy (*PE*).

Given equilibrium conditions, reduced form feed and farm price equations can be defined as follows:

$$\ln PFD_t = \frac{b_0 - a_0}{a_1 - b_1} + \frac{b_2}{a_1 - b_1} \ln PF_t^e - \frac{a_2}{a_1 - b_1} \ln PCO_t - \frac{a_3}{a_1 - b_1} \ln PSO_t \quad (5.5)$$

$$- \frac{a_4}{a_1 - b_1} \ln PCT_t - \frac{a_5}{a_1 - b_1} \ln PWH_t + \frac{b_3 - a_6}{a_1 - b_1} \ln PE_t + (\varepsilon_t^d - \varepsilon_t^s)$$

$$\ln PF_t = \frac{d_0 - c_0}{c_1 - d_1} - \frac{c_2}{c_1 - d_1} \ln PFD_{t-18} + \frac{d_2}{c_1 - d_1} \ln PP_t + \frac{d_3 - c_3}{c_1 - d_1} \ln PE_t + (\mu_t^d - \mu_t^s) \quad (5.6)$$

Let $a_0^* = \frac{b_0 - a_0}{a_1 - b_1}$, $a_1^* = \frac{b_2}{a_1 - b_1}$, $a_2^* = -\frac{a_2}{a_1 - b_1}$, $a_3^* = -\frac{a_3}{a_1 - b_1}$,

$a_4^* = -\frac{a_4}{a_1 - b_1}$, $a_5^* = \frac{b_3 - a_5}{a_1 - b_1}$, and $\varepsilon_t = \varepsilon_t^d - \varepsilon_t^s$, equation (5.5) can be rewritten as:

$$\ln PFD_t = a_0^* + a_1^* \ln PF_t^e + a_2^* \ln PCO_t + a_3^* \ln PSO_t + a_4^* \ln PCT_t + a_5^* \ln PWH_t + a_6^* \ln PE_t + \varepsilon_t \quad (5.7)$$

Let $c_0^* = \frac{d_0 - c_0}{c_1 - d_1}$, $c_1^* = -\frac{c_2}{c_1 - d_1}$, $c_2^* = \frac{d_2}{c_1 - d_1}$, $c_3^* = \frac{d_3 - c_3}{c_1 - d_1}$,

and $\mu_t = \mu_t^d - \mu_t^s$, equation (5.6) can be rewritten as :

$$\ln PF_t = c_0^* + c_1^* \ln PFD_{t-18} + c_2^* \ln PP_t + c_3^* \ln PE_t + \mu_t \quad (5.8)$$

Given economic theory, $a_1^* > 0$, $a_2^* > 0$, $a_3^* > 0$, $a_4^* > 0$, $a_5^* > 0$. The sign of a_6^* is indeterminate given that energy is used in both feed and catfish production. $c_1^* > 0$, $c_2^* > 0$. The sign of c_3^* in indeterminate given that energy is used at both the farm and processor levels.

In a cointegration framework, equations (5.7) and (5.8) are the long-run relationships between feed and farm prices and their regressors (Pesaran, Shin, and Smith, 2001).

5.2 Estimation Method

5.2.1 The ARDL Model

The error correction version of the ARDL model is used to estimate the reduced form relationships between feed prices and farm prices, and the exogenous variables. The

ARDL model yields both long-run and short-run relationships between the variables of interest.

Given the long-run relationships (5.7) and (5.8), the error correction version of the ARDL model can be written as follows:

$$\Delta \ln PFD_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta \ln PFD_{t-i} + \sum_{i=0}^{n1} \phi_{1i} \Delta \ln PF^{e}{}_{t-i} + \sum_{i=0}^{n2} \phi_{2i} \Delta \ln PCO_{t-i} \quad (5.9)$$

$$+ \sum_{i=0}^{n3} \phi_{3i} \Delta \ln PSO_{t-i} + \sum_{i=0}^{n4} \phi_{4i} \Delta \ln PCT_{t-i} + \sum_{i=0}^{n5} \phi_{5i} \Delta \ln PWH_{t-i}$$

$$+ \sum_{i=0}^{n6} \phi_{6i} \Delta \ln PE_{t-i} + \lambda_0 \ln PFD_{t-1} + \lambda_1 \ln PF^{e}_{t-1} + \lambda_2 \ln PCO_{t-1}$$

$$+ \lambda_3 \ln PSO_{t-1} + \lambda_4 \ln PCT_{t-1} + \lambda_5 \ln PWH_{t-1} + \lambda_6 \ln PE_{t-1} + \nu_t$$

$$\Delta \ln PF_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln PF_{t-i} + \sum_{i=0}^{q1} \theta_{1i} \Delta \ln PP_{t-i} + \sum_{i=0}^{q2} \theta_{2i} \Delta \ln PFD_{t-18-i} \quad (5.10)$$

$$+ \sum_{i=0}^{q3} \theta_{3i} \Delta \ln PE_{t-i} + \omega_0 \ln PF_{t-1} + \omega_1 \ln PP_{t-1}$$

$$+ \omega_2 \ln PFD_{t-19} + \omega_3 \ln PE_{t-1} + \upsilon_t$$

Δ represents the first difference of each variable. For instance, $\Delta \ln PF_t = \ln PF_t - \ln PF_{t-1}$. The *m, n's, p* and *q's* are lag orders, and ν_t and υ_t are the errors which are assumed serially uncorrelated. ϕ and θ represent the short-run dynamics between the dependent and independent variables in equation (5.9) and (5.10), respectively. λ and ω give the long-run relationships between the dependent and independent variables in equation (5.9) and (5.10), respectively.

To test for cointegration, the optimal lag orders (*m, n, p* and *q*) in equations (5.9) and (5.10) are determined first. Following Pesaran, Shin, and Smith (2001), Baek and

Koo (2007), Bahmani (2008), Oskooee and Ng (2002) and Atkins and Coe (2002), the AIC and SBC criterions are used to determine the optimal lag orders.

No-cointegration implies that $\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$ in equation (5.9) and $\gamma_0 = \gamma_1 = \gamma_2 = \gamma_3 = 0$ in equation (5.10). Following Pesaran, Shin, and Smith (2001), a F-test is used to test for the cointegration. The F-statistic for the cointegration restrictions does not follow the typical F distribution. Pesaran, Shin, and Smith (2001) give the critical values for this test where they derived upper bound critical values when all variables are $I(1)$ and lower bound critical values when all the variables are $I(0)$. Following Bahmani (2008), lagrange multiplier (LM) statistics are used to test the hypothesis of no serial correlation with each lag order.

Once the appropriate lag orders are chosen and the existence of cointegration is proven, the long-run relationships (5.7) and (5.8) are estimated by Ordinary Least Square (OLS). The lag residuals are then used to estimate equation (5.9) and (5.10).

Let ECT_t^{PFD} and ECT_t^{PF} denote the error correction terms for the feed and farm markets, respectively, where

$$ECT_t^{PFD} = \ln PFD_t - (\hat{a}_0^* + \hat{a}_1^* \ln PF_t^e + \hat{a}_2^* \ln PCO_t + \hat{a}_3^* \ln PSO_t + \hat{a}_4^* \ln PCT_t$$

$$+ \hat{a}_5^* \ln PWH_t + \hat{a}_6^* \ln PE_t) = \hat{\varepsilon}_t$$

and

$$ECT_t^{PF} = \ln PF_t - (\hat{c}_0^* + \hat{c}_1^* LPFD_{t-18} + \hat{c}_2^* \ln PP_t + \hat{c}_3^* \ln PE_t) = \hat{\mu}_t$$

With the error correction terms, equation (5.9) and (5.10) can be rewritten as follows:

$$\Delta \ln PFD_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta \ln PFD_{t-i} + \sum_{i=0}^{n1} \phi_{1i} \Delta \ln PF^{e}{}_{t-i} + \sum_{i=0}^{n2} \phi_{2i} \Delta \ln PCO_{t-i} \tag{5.11}$$

$$+ \sum_{i=0}^{n3} \phi_{3i} \Delta \ln PSO_{t-i} + \sum_{i=0}^{n4} \phi_{4i} \Delta \ln PCT_{t-i} + \sum_{i=0}^{n5} \phi_{5i} \Delta \ln PWH_{t-i}$$

$$+ \sum_{i=0}^{n6} \phi_{6i} \Delta \ln PE_{t-1} + \lambda ECT_{t-1}^{PFD} + \nu_t$$

$$\Delta \ln PF_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln PF_{t-i} + \sum_{i=0}^{q1} \theta_{1i} \Delta \ln PP_{t-i} + \sum_{i=0}^{q2} \theta_{2i} \Delta \ln PFD_{t-18-i} \tag{5.12}$$

$$+ \sum_{i=0}^{q3} \theta_{3i} \Delta \ln PE_{t-i} + \omega ECT_{t-1}^{PF} + \upsilon_t$$

Equation (5.11) and (5.12) are also estimated by OLS.

5.2.2 Elasticities

Since the ARDL model and the long-run relationships are all in log linear form, the parameters are elasticites. As mentioned in section 5.1, all the parameters in equation (5.7) should be positive except for the energy price parameters. This indicates that the long-run feed price elasticities with respect to the ingredient prices and farm prices should be positive. That is, if an ingredient price or the farm price increases by one percent, feed price should increase by the percentage indicated by the elasticity. For instance, in the long-run, if the farm price increases by one percent, the feed price should increase by a_1^* percent. Short-run feed price elasticities with respect to farm and ingredient prices, from equation (5.11), are also expected to be positive. The signs of the short-run and long-run elasticities with respect to energy prices (a_6^* and ϕ_{6i}) are uncertain.

With the exception of energy prices, the short-run and long-run catfish farm price elasticities are expected to be positive. For instance, in the short-run and long-run, if the feed price increases by one percent, the farm price should increase by θ_{2i} and c_1^* percent, respectively. The short-run impact of energy price on the catfish farm price is uncertain.

In the long-run, the energy price directly affects the farm price, and indirectly affects the farm price through feed prices. Therefore, the elasticity of the farm price with respect to energy prices in the long-run is:

$$\gamma_{PE}^{lr} = \frac{\%\Delta PF}{\%\Delta PFD}\frac{\%\Delta PFD}{\%\Delta PE} + \frac{\%\Delta PF}{\%\Delta PE} = c_1^* a_6^* + c_3^*$$

Feed and farm price elasticities with respect to ethanol production are also derived. Let ρ represent the percentage change in corn prices given a one percentage change in ethanol production, the short-run feed price elasticity with respect to ethanol production is:

$$\eta_{ethanol}^{sr} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} = \phi_{2i}\rho \qquad i = 0, 1, \ldots, n2$$

i= 0 indicates the initial effect of the energy price on feed prices. *i*= 1 indicates the first period effect of the energy price on feed prices. *i*= *n*2 indicates the *n*2 period effect of the energy price on feed prices.

The long-run feed price elasticity with respect to ethanol production is:

$$\eta_{ethanol}^{lr} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} = a_2^*\rho$$

ϕ_{2i}, a_2^* and ρ are expected to be positive. Therefore, the short-run and long-run feed price elasticities with respect to ethanol production should also be positive.

Given the 18-month lag in feed prices, ethanol production only affects farm prices in the long-run. The long-run farm price elasticity with respect to ethanol production is:

$$\gamma_{ethanol}^{lr} = \frac{\%\Delta PF}{\%\Delta ethanol} = \frac{\%\Delta PF}{\%\Delta PFD}\frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} = c_1^* a_2^* \rho$$

Because the expected signs of c_1^* and a_2^* are positive, the long-run effect of ethanol production on the catfish farm price should also be positive.

CHAPTER VI

RESULTS

6.1 Data and Data Sources

Monthly data from January 1996 to December 2007 are used to estimate the ARDL feed and farm price equations (5.11) and (5.12), and the long-run feed and farm price equations (5.7) and (5.8). There are a total of 144 observations. Data sources include: the National Agricultural Statistics Service (NASS), Bureau of Labor Statistics (BLS), Hanson and Sites (2008), and USDA Economic Research Services (ERS). Feed prices (*PFD*) are from Hanson and Sites (2008). Catfish farm prices (*PF*) and processed catfish prices (*PP*) are from NASS. Corn prices (*PCO*), soybean meal prices (*PSO*), and cottonseed meal prices (*PCT*) are from ERS. Energy prices (*PE*) are from BLS. Descriptive statistics are given in Table 6.1.

The average feed price during the 1996-2007 period was $236.65/ton. Catfish prices at the farm and the processor levels were $0.71/lb and $2.29/lb. Corn, soybean meal, and cottonseed meal prices averaged $2.86/bushel, $197.91/ton and $149.57/ton, respectively. The average energy price index was 80.51. Corn prices reached a high of $5.17/bushel in May 1996, and a low of $1.91/bushel in July and August 2000. Feed prices reached a high of $337.48/ton in December 2007, and a low of $186 /ton in May1999. The highest farm price was $0.84/lb (October 2006), and the lowest farm price was $0.53/lb (January 2003).

Table 6.1 Descriptive Statistics: 1996-2007.

Variable	Unit	Mean	Standard Deviation	Minimum	Maximum
PFD	$/ton	236.65	35.08	186.00	337.48
PF	$/lb	0.71	0.08	0.53	0.84
PCO	$/bushel	2.86	0.72	1.91	5.17
PSO	$/ton	197.91	46.63	132.30	331.28
PCT	$/ton	149.57	29.89	100.65	224.50
PP	$/lb	2.29	0.14	2.02	2.59
PE	index	80.51	3.98	74.09	90.40

Note that the index of No 2. diesel fuel price (taking 1982 as the base year) is used to estimate the model, and the index is deflated by the CPI while other price variables are not. Several energy price indexes are tried and compared, such as deflated and undeflated price index of natural gas, and deflated and undeflated price index of electric power. The model turns out to be econometrically better when using deflated index of No 2. diesel price. Actual energy prices are other possible variable choices, and it is possible that the model would provide better estimation results if actual energy prices are used.

6.2 Model Results

6.2.1 Lag Orders and Cointegration Test

The ARDL feed price equation (5.9) is estimated using OLS assuming lag orders from 0 to 4. Results are shown in Table 6.2. Equation (5.9) is estimated without wheat middling prices because preliminary results showed that once corn and soybean meal prices were included in the model, wheat middling prices were not significant. The Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC) are used for determining the optimal lag order. Tests for serial correlation and the existence of cointegration are done for each lag order.

The AIC and SBC are commonly used for determining the optimal lag order. The AIC and SBC are reported for each estimation and then compared. In order for this analysis to be valid, serial correlation can not exist in the model. Following Pesaran, Shin, and Smith (2001), autocorrelation up to the fourth order, AR(1) to AR(4), are considered. The F-statistics for the cointegration test are also reported for each lag order.

Table 6.2 ARDL Feed Price Results and Cointegration F-Statistics

Lag Order	AIC	SBC	$\chi^2_{sc}(1)$	$\chi^2_{sc}(2)$	$\chi^2_{sc}(3)$	$\chi^2_{sc}(4)$	F-statistic
0	600.67	562.25	11.33*	12.35*	12.35*	12.35*	3.76
1	621.79	568.71	0.05	2.37	2.54	4.43	3.38
2	610.41	539.81	0.41	2.19	2.80	6.22	1.90
3	596.85	508.82	4.83*	5.09	5.13	7.72	1.78
4	587.77	482.39	0.01	1.88	2.71	10.69*	1.96

Note: $\chi^2_{sc}(1)$, $\chi^2_{sc}(2)$, $\chi^2_{sc}(3)$, and $\chi^2_{sc}(4)$ are the LM statistics for testing serial correlation.
* indicates the existence of correlation at each lag order.
The F-statistics from 5 percent upper bound critical value bounds is 3.28. The critical value is retrieved from Parasan, Shin, and Smith (2001).

The AIC and SBC values for the ARDL model with no lags (lag order =0) are 600.67 and 562.25, respectively. When one-period lags (lag order =1) are added to the model, the AIC and SBC increase. This indicates that the model with one-period lags is better than the model with no lags. Adding two-, three-, and four-period lags to the model does not increase the AIC and SBC, indicating that the model with one-period lags is the optimal.

χ^2_{sc} is the Lagrange multiplier (LM) statistic for autocorrelation. The LM statistics show that the model with no lags has AR(1), AR(2), AR(3), and AR(4) problems. When addding one-period lags to the model, autocorrelation is mitigated.

The F-tests for cointegration are performed for each lag order. If the F-statistic exceeds the upper bound critical value given by Pesaran, Shin, and Smith (2001), the variables are cointegrated. Results show that the model with one-period lags has a F-statistic of 3.38 which is higher than the upper bound critical value (3.28). This indicates that the variables are cointegrated in the one-period lag model. Given that the model with one-period lags has the highest AIC and SBC values, does not have autocorrelation problems, and the variables are cointegrated, one-period lags are assumed when estimating the error correction version of the ARDL feed price equation (5.11).

The ARDL farm price equation (5.10) is estimated using OLS assuming lag orders from 0 to 4. As before, the AIC and SBC criterion are reported and compared to determine the optimal lag order. Autocorrelation, AR(1) to AR(4), are considered for each lag order, and F-test are conducted for cointegration. Results are shown in Table 6.3.

The model with no lags has an AIC and SBC value of 669.13 and 643.68, respectively. At higher lag orders, the values of the AIC and SBC decrease. This indicates that the model with no lags is the optimal model. The LM statistics show that when assuming a lag order of 0 or 1, the model has no autoccorelation problems. Results of the F-test for cointegration show that the model with a lag order of 0 or 1 has a F-statistic of 6.79 and 4.47, respectively, which are significantly higher than the 5 percent upper bound critical value of 3.49. This implies that the variables are cointegrated in these models. Given that the model with no lags has the highest AIC and SBC values, does not have autocorrelation problems, and the variables are cointegrated, no lags are assumed when estimating the error correction version of the ARDL farm price equation (5.12).

Table 6.3 ARDL Farm Price Results and Cointegration F-Statistics

Lag Order	AIC	SBC	$\chi^2_{sc}(1)$	$\chi^2_{sc}(2)$	$\chi^2_{sc}(3)$	$\chi^2_{sc}(4)$	F-stastic
0	669.13	643.68	0.24	2.96	4.12	4.46	6.79
1	663.82	629.98	2.36	3.11	3.43	9.07	4.47
2	652.21	607.21	0.68	3.49	3.50	10.03*	2.96
3	640.84	584.76	0.00	7.90*	8.28*	12.60*	2.22
4	631.17	564.07	4.08*	5.42	9.16*	13.07*	1.74

Note: $\chi^2_{sc}(1)$, $\chi^2_{sc}(2)$, $\chi^2_{sc}(3)$, and $\chi^2_{sc}(4)$ are the LM statistics for testing serial correlation.
* indicates the existence of correlation at each lag order.
The F-statistics from 5 percent upper bound critical value bounds is 3.49. The critical value is retrieved from Parasan, Shin, and Smith (2001).

6.2.2 Estimation Results

The long-run relationship between the feed price and its resgressors (5.7) is estimated using OLS. The farm price lagged one month is used as a proxy for the expected farm price. Estimation results are as follows:

$$\ln PFD_t = \underset{(0.567)}{0.523} - \underset{(0.048)}{0.055} \ln PF_t^e + \underset{(0.036)}{0.224} \ln PCO_t + \underset{(0.041)}{0.328} \ln PSO_t \qquad (6.1)$$

$$+ \underset{(0.046)}{0.051} \ln PCT_t + \underset{(0.126)}{0.616} \ln PE_t + \hat{\varepsilon}_t$$

$\overline{R^2} = 0.84$

In the long-run, the independent variables are significant at the 0.01 level, except for the cottonseed meal price, expected farm price, and the constant term. Equation (6.1) indicates that in the long-run, a one percent increase in the price of corn and soybean meal causes feed prices to increase by 0.224 and 0.328 percent, respectively. The long-run feed price elasticity with respect to energy prices indicates that a one percent increase in energy prices leads to a 0.616 percent increase in the feed price. This positive elasticity suggests that the decrease in feed supply due to an energy price increase (supply effect) outweighs the decrease in feed demand due to an energy price increase (demand effect). It is likely that energy is more important to catfish feed production than to farm level catfish production.

The ARDL feed price equation (5.11) is estimated using OLS. Recall that equation (5.11) is different from (5.9) in that the long-run variables are replaced with an error correction term (ECT) where $ECT_{t-1}^{PFD} = \hat{\varepsilon}_{t-1}$ in this instance. As shown in Table 6.2, the model with one-period lags is the optimal. Therefore, one-period lags are assumed for equation (5.11). As before, the farm price lagged one month is used as the expected farm price.

The estimates in Table 6.4 are considered to be short-run feed price elasticities. The short-run relationships between the feed price and the regressors are for the most part significant at the 0.01, 0.05, and 0.10 levels, with the exception of the expected farm price in the initial period, the price of soybean meal in the lagged period, and the constant term.

Table 6.4 ARDL Catfish Feed Price Estimates

Variable	Estimate	Standard Error	P-value
$\Delta \ln PFD_t$	-0.138	0.078	0.081
$\Delta \ln PF_t^e$	-0.138	0.116	0.238
$\Delta \ln PF_{t-1}^e$	0.231	0.116	0.048
$\Delta \ln PCO_t$	0.075	0.039	0.055
$\Delta \ln PCO_{t-1}$	0.156	0.041	0.000
$\Delta \ln PSO_t$	0.121	0.032	0.000
$\Delta \ln PSO_{t-1}$	0.028	0.038	0.462
$\Delta \ln PCT_t$	0.105	0.030	0.008
$\Delta \ln PCT_{t-1}$	0.089	0.031	0.005
$\Delta \ln PE_t$	0.305	0.113	0.008
$\Delta \ln PE_{t-1}$	-0.204	0.115	0.077
ECT_{t-1}^{PFD}	-0.135	0.045	0.003
Constant	0.002	0.002	0.458
$\chi_{sc}^2(1)$ 0.232 [0.630]	$\chi_{sc}^2(4)$ 0.188 [0.880]	AIC=619.89 SBC=581.55	$\overline{R^2}$ =0.50

Notes: *ECT* is the error correction term. χ^2 distribution (with the p-value in brackets) are the Lagrange multiplier statistics for AR(1) and AR(4).

Results show that an increase in expected farm prices has no effect on the feed price in the initial period, but has a positive effect (0.231) in the lagged period. In the initial period, the feed price elasticity with respect to the corn price, soybean meal price, and cottonseed meal price are 0.075, 0.121, and 0.105, respectively. In the lagged period, the feed price elasticity with respect to corn and cottonseed meal prices are 0.156 and 0.089, respectively. An increase in energy prices has a positive effect on the feed price in the initial period (0.305), and a negative effect in the lagged period (-0.204). This implies that the supply effect of energy prices on the feed price outweighs the demand effect in the initial period, but in the lagged period, the supply effect is smaller than the demand effect.

The estimate for ECT_{t-1}^{PFD} is negative and significant at the 0.01 level. The negative sign ensures that a long-run equilibrium is achieved. The *ECT* estimate (-0.135) indicates that feed prices adjust approximately 13.5% to the long-run equilibrium in one month, and that it takes a little more than 7 months (1/0.135=7.4 months) to correct long-run disequilibria (Baek and Koo, 2007).

The long-run relationship between the farm price and its resgressors (5.8) is estimated using OLS. Estimation results are as follows:

$$\ln PF_t = \underset{(0.228)}{-1.594} + \underset{(0.019)}{0.221} \ln PFD_{t-18} + \underset{(0.041)}{1.702} \ln PP_t - \underset{(0.054)}{0.301} \ln PE_t + \hat{\mu}_t \quad (6.2)$$

$\overline{R^2} = 0.95$

All independent variables are significant at the 0.01 level. Equation (6.2) indicates that in the long-run, a one percentage increase in the processor price and feed price (lagged 18 months) causes the catfish farm price to increase by 1.702 and 0.211 percent, respectively. The long-run farm price elasticity with respect to energy prices is -0.301. This indicates that the demand effect of energy prices on the farm price is greater than the supply effect. It is likely that energy is more important to catfish production at the processor level than to production at the farm level.

In the long-run, energy prices have a direct effect on the farm price and an indirect effect on the farm price through feed prices. Given the long-run farm price elasticity with respect to the energy price (-0.301), long-run farm price elasticity with respect to feed prices (0.221), and the long-run feed price elasticity with respect to the energy price (0.616), the farm price elasticity with respect to energy prices accounting for both effects is:

$$\gamma_{PE}^{lr} = \frac{\%\Delta PF}{\%\Delta PFD}\frac{\%\Delta PFD}{\%\Delta PE} + \frac{\%\Delta PF}{\%\Delta PE} \tag{6.3}$$

$$= 0.211(0.616) - 0.301 = -0.171$$

The total effect of energy prices indicates that the demand effect of energy prices on the farm price still dominates the supply effect when considering the impact of feed prices. However, the total effect of energy prices is smaller than the direct effect when the effect of energy prices on feed prices is considered.

The ARDL farm price equation (5.12) is estimated using OLS. As shown in Table 6.3, the model with no lags is the optimal. However, adding lagged processor prices improved results. Therefore, the model is estimated with no lags with the exception of processer prices. As before, equation (5.12) is different from (5.10) in that the long-run variables are replaced with an error correction term where $ECT_{t-1}^{PF} = \mu_{t-1}$, which is the lag residual from equation (6.2). Results are shown in Table 6.5.

The short-run relationships between the feed price and the regressors are all significant at the 0.01 level. Results show that a one percentage increase in the feed price (lagged 18 months) causes the farm price to increase by 0.106 percent. The farm price elasticity with respect to the current and one month lagged catfish price at the processor level are 0.888 and 0.262, respectively. The energy price has a negative impact on catfish prices at the farm level (-0.152). This indicates that the demand effect of energy prices on farm prices dominates the supply effect.

The estimate for ECT_{t-1}^{PF} (-0.254) is negative and significant at the 0.01 level. This indicates that the farm price adjusts approximately 25.4% to the long-run equilibrium in one month, and that it takes almost 4 months (1/0.254=3.9 months) to correct long-run disequilibria.

Table 6.5 ARDL Catfish Farm Price Estimates

Variable	Estimate	Standard Error	P-value
$\Delta \ln PF_{t-1}$	0.336	0.083	0.000
$\Delta \ln PP_t$	0.888	0.105	0.000
$\Delta \ln PP_{t-1}$	0.262	0.120	0.032
$\Delta \ln PFD_{t-18}$	0.112	0.041	0.007
$\Delta \ln PE_t$	-0.152	0.067	0.025
ECT_{t-1}^{PF}	-0.255	0.059	0.001
Constant	-0.001	0.001	0.072
$\chi_{sc}^2(1)$ 2.060 [0.151]	$\chi_{sc}^2(4)$ 5.681 [0.224]	AIC=675.66 SBC=655.87	$\overline{R}^2$ =0.64

Notes: *ECT* is the error correction term. χ^2 distribution (with the p-value in brackets) are the Lagrange multiplier statistics for AR(1) and AR(4).

6.3 The Effects of Ethanol Production

The main purpose of this study is to assess the impact of U.S. ethanol production on catfish feed prices and catfish prices at the farm level. Given the relationship between corn prices and ethanol production, catfish feed and farm price elasticities with respect to ethanol production can be calculated using model estimates. The relationship between corn prices and ethanol production is taken from previous studies.

According to Park and Fortenbery (2007), for every one percentage increase in ethanol production, corn prices increased by 0.16 percent in the short-run. Using this elasticity, the short-run feed price elasticities are as follows:

$$\eta_{ethanol}^{sr(0)} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \quad (6.4)$$

$$= 0.075 \times 0.16 = 0.012$$

$$\eta_{ethanol}^{sr(1)} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \quad (6.5)$$

$$= 0.156 \times 0.16 = 0.025$$

Equation 6.4 and 6.5 show that the responsiveness of the catfish feed price to a percentage increase in ethanol production is 0.012 percent in the initial period, and 0.025 percent in the lag period. This indicates that a one percent increase in ethanol production the current month results in a 0.012 percent increase in feed prices in the current month and a 0.025 percent increase in feed prices one month later. Given that it takes 18 months for feed prices to affect farm prices, ethanol production should have no effect on catfish farm prices in the short-run.

To assess the long-run effects of ethanol production on catfish feed and farm prices, the relationship between ethanol production and corn prices is taken from two studies: Tanheripour and Tyner (2008), and the U.S. Department of Energy (DOE). DOE results are reported in Muhammad and Kebede (2009). Between 2004 and 2008, corn prices increased from $2 to $6 per bushel. Taheripour and Tyner (2008) state that of the total increase, 25 percent was due to U.S. ethanol subsidies. During this period, ethanol production increased from 3,402,378,000 gallons in 2004 to approximately 8,382,570, 000 gallons in 2008, an increase of 146 percent (Energy Information Administration, 2009). Assuming that the increase in ethanol production was solely due to government subsidies, the corn price elasticity with respect to ethanol production is

$$\frac{\%\Delta PCO}{\%\Delta ethanol} = \frac{[(6-2)/2]\times 0.25}{1.46} = 0.342 \qquad (6.6)$$

Using equation (6.6), the long-run feed and farm price elasticities with respect to ethanol production are

$$\eta_{ethanol}^{lr} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \qquad (6.7)$$

$$= 0.224 \times 0.342 = 0.077$$

$$\gamma_{ethanol}^{lr} = \frac{\%\Delta PF}{\%\Delta ethanol} = \frac{\%\Delta PF}{\%\Delta PFD}\frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \qquad (6.8)$$

$$= 0.211 \times 0.224 \times 0.342 = 0.016$$

These elasticities show that the responsiveness of catfish feed and farm prices to percentage increases in ethanol production are 0.077 and 0.016 percent, respectively. Although both farm and feed prices increase when ethanol production expands, farmers may still lose profits given the relatively smaller increase in farm prices when compared to feed prices.

It can easily be shown that for every one percent increase in feed prices, farm prices must increase by 0.4 percent in order for profits to be the same. Let *k* be the profit received by catfish farmers, *Q* be the quantity of fish, *F* be the quantity of feed, and *OC* be other costs besides feed. Then *k* is

$$k = PF \times Q - PFD \times F - OC \tag{6.9}$$

If the feed price increases by one percent, and farm prices change by ($j \times 100$) percent, profit can be rewritten as:

$$k^* = (1+j)PF \times Q - (1.01)PFD \times F - OC \tag{6.10}$$

If $k^* \geq k$, then

$$j \geq \frac{(0.01)PFD}{PF}\frac{F}{Q} \tag{6.11}$$

According to Dorman (2009), to grow a fingerling to market size (1.5 pounds), requires 3.73 pounds of feed where the input-output ratio (F/Q) is 2.5.

Using the average farm price of $0.72/lb and feed price of $0.115/lb, *j* is calculated as:

$$j \geq \frac{(0.01 \times 0.115)}{0.72} \times 2.5 = 0.004 \tag{6.12}$$

Equation (6.12) indicates that to keep profits at the same level, farm prices must increase by at least 0.4 percent when feed prices increase by one percent. However, the estimated farm price elasticity with respect to feed prices (0.211) is smaller than 0.4. This implies that catfish farmers will lose profits when feed prices increase. Therefore, although both feed and farm prices will increase when ethanol production expands, farm profits will still decrease.

According to the DOE, 54 percent of the increase in corn prices from June 2007 to July 2008 was due to the growth in ethanol production (Muhammad and Kebede, 2009). Ethanol production increased from 549,486,000 gallons to 799,764,000 gallons during this period, an increase of 46 percent (Energy Information Administration, 2009). Corn prices increased from \$3.50/bushel in June 2007 to \$5.20/bushel in July 2008, an increase of 49 percent (Economic Research Service, 2009). Based on this study, the corn price elasticity with respect to ethanol production is

$$\frac{\%\Delta PCO}{\%\Delta ethanol} = \frac{[(5.2-3.5)/3.5]\times 0.54}{0.46} = 0.570 \qquad (6.13)$$

Using equation (6.13), the long-run feed and farm price elasticities with respect to ethanol production are

$$\eta_{ethanol}^{lr} = \frac{\%\Delta PFD}{\%\Delta ethanol} = \frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \qquad (6.14)$$

$$= 0.224 \times 0.570 = 0.128$$

$$\gamma_{ethanol}^{lr} = \frac{\%\Delta PF}{\%\Delta ethanol} = \frac{\%\Delta PF}{\%\Delta PFD}\frac{\%\Delta PFD}{\%\Delta PCO}\frac{\%\Delta PCO}{\%\Delta ethanol} \qquad (6.15)$$

$$= 0.211 \times 0.224 \times 0.570 = 0.027$$

These elasticities show that the responsiveness of the catfish feed and farm prices to percentage increases in ethanol production are 0.128 and 0.027 percent, respectively. Given that corn prices are more sensitive to the increase in ethanol production using DOE estimates, long-run feed and farm price elasticities with respect to ethanol production are greater than the results using the Taheripour and Tyner estimates.

As before, increased ethanol production should lead to a decrease in farm profits. However, the decrease in profits is solely due to the farm price elasticity with respect to feed price (0.211) being smaller than 0.4.

CHAPTER VII

CONCLUSION

The goal of this research was to estimate how the rise in corn prices caused by the increase in ethanol production impacted catfish feed and farm prices. The research followed two steps. First, the econometric relationship between catfish feed prices and ingredient prices, especially corn and soybean meal prices was examined. Second, the econometric relationship between catfish farm and feed prices was estimated. Short-run and long-run elasticites were obtained to show how corn prices impacted catfish farm and feed prices. Given the relationship between ethanol production and corn prices, the impact of ethanol production on the U.S. catfish sector was assessed.

Using monthly data from January 1996 to December 2007, an ARDL model and bounds testing procedure were used to test the existence of cointegration between the catfish feed price and corn, soybean meal, and cottonseed meal prices, as well as energy prices and expected catfish prices at the farm level. Catfish feed prices were found to have a long-run relationship with the independent variables of interest. The existence of cointegration between the farm price and feed prices, energy prices, and processor prices was also tested. Catfish farm prices were also found to have a long-run relationship with the independent variables.

Feed and farm price elasticities with respect to energy prices were highlighted. Both the short-run and long-run feed price elasticites with respect to energy prices were positive. That is, the decrease in feed supply due to an energy price increase outweighs the decrease in feed demand due to an energy price increase. It is likely that energy is more important to catfish feed production than to catfish production at the farm level.

Both the short-run and long-run farm price elasticities with respect to energy prices were negative. This implies that the decrease in farm demand due to an energy price increase outweighs the decrease in farm supply due to an energy price increase. It is likely that energy is more important to catfish production at the processor level than to production at the farm level.

Given the positive feed price elasticity with respect to energy prices and the negative farm price elasticity with respect to energy prices, catfish farmers will incur a profit loss when energy prices increase. According to the Bureau of Labor Statistics, diesel prices increased by 317 percent from 2002 to 2008. Such an increase should have a negative impact on catfish farm prices and a positive impact on feed prices. This may be one reason why catfish farmers have gone out of business.

The short-run and long-run impact of U.S. ethanol production on catfish feed prices was assessed, as well as the long-run farm price elasticities with respect to ethanol production. In the short-run, the responsiveness of the catfish feed price to a percentage increase in ethanol production is 0.012 in the initial period and 0.025 in the lag period, indicating that a one percent increase in ethanol production results in a 0.012 percent increase in feed prices in the current month and a 0.025 percent increase in feed prices one month later.

In the long-run, catfish feed and farm prices elasticities with respect to ethanol production were found to be positive. This indicates that both catfish feed and farm prices should increase with U.S. ethanol production expansion. However, catfish farmers will lose profit because the estimated farm price elasticity with respect to feed prices in this study was smaller than the necessary change that would keep profits the same.

The results of this research will benefit catfish feed producers, catfish producers at the farm level, catfish processors, policy makers, and economists. With the feed price estimates, catfish feed producers will be able to predict future feed prices with respect to changes in ingredient prices, energy prices, and farm prices. The model estimates also provide catfish farmers with information about the relationship between energy, feed and farm prices. They will be able to predict how much they need to pay for feed and how much they will receive when selling to processors. When energy prices and ethanol production increase, farmers can take reasonable actions knowing that they may lose profits. Model estimates also make it easier for processors to predict how much they will pay farmers for catfish.

This study gives policy makers and economists a better understanding of what has happened to the catfish industry. The results of this study show that increasing energy prices led to higher feed prices and lower farm prices, squeezing farm profits. Expanding ethanol production caused higher feed and farm prices. However, the increase in farm prices was lower than the increase in feed prices. As a result, farmers will likely lose profits even though both feed and farm prices increase.

Some limits exist within this study. First, the elasticities in this study do not account for differences in how the dependent variables respond to increases in the independent variables as oppose to decreases in the independent variables. For instance, the feed price elasticity in this study gives the changes in feed prices with respect to changes in corn prices. However, it could be that feed prices response differently when corn prices increase versus corn prices decrease. The same could be said of the farm price elasticity with respect to feed prices where the direction of the feed price change is not accounted for in the model.

Second, the same energy price is assumed for each sector, indicating that feed producers, catfish farmers, and processors use the same energy. Since energy prices specific to feed producers, catfish farmers, and processors are difficult to find, the energy price index for the diesel fuel is used as a proxy to estimate the model. However, feed producers could use diesel fuel, while processers could use electricity.

Finally, since 2008 data are available for all the variables except feed prices, the data range in this study stops at the end of 2007. Corn prices increased 44.7 percent in 2008 (Economic Research Service, 2009b). Such an increase could make the estimates different when using more recent data to estimate the model.

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APPENDIX

SAS CODE

```
/*ARDL Model:reduced form equation for feed price*/

/*create datafile*/
libname New1 'C:\Documents and Settings\agecon\Desktop\Thesis\Thesis';

/*monthly data*/
proc import out = Work.SAEA
DATAFILE="C:\Documents and Settings\agecon\Desktop\Thesis\
Thesis\Catfishfeed_correction.xls"
DBMS=EXCEL REPLACE;
SHEET = "monthly";
 GETNAMES=YES;
    MIXED=NO;
    SCANTEXT=YES;
    USEDATE=YES;
    SCANTIME=YES;
run;

/*create log terms*/
data Work.SAEA;
set Work.SAEA;
LPfeed = log(Pfeed);
Pflag = lag(Pf);
LPf = log(Pflag);
LPco = log(Pco);
LPso= log(Pso);
LPwh   = log(Pwh);
LPct = log(Pct);
LPe = log(Pe);
run;

/*create lag terms*/
data Work.SAEA;
set Work.SAEA;
LPfeed1 = lag(LPfeed);
LPf1 = lag(LPf);
LPso1 = lag(LPso);
LPwh1= lag(LPwh);
LPct1 = lag(LPct);
LPco1 = lag(LPco);
LPe1 = lag(LPe);
run;

/*create difference terms*/
data Work.SAEA;
set Work.SAEA;
DPfeed = LPfeed - LPfeed1;
DPfeed1 = lag(DPfeed);
DPfeed2 = lag2(DPfeed);
DPfeed3 = lag3(DPfeed);
DPfeed4 = lag4(DPfeed);
DPf = LPf - LPf1;
DPf1 = lag(DPf);
DPf2 = lag2(DPf);
DPf3 = lag3(DPf);
DPf4 = lag4(DPf);
```

```
DPco = LPco - LPco1;
DPco1 =lag(DPco);
DPco2 =lag2(DPco);
DPco3 =lag3(DPco);
DPco4 =lag4(DPco);
DPso = LPso -LPso1;
DPso1 =lag(DPso);
DPso2 =lag2(DPso);
DPso3 =lag3(DPso);
DPso4 =lag4(DPso);
DPwh = LPwh - LPwh1;
DPwh1 =lag(DPwh);
DPwh2 =lag2(DPwh);
DPwh3 =lag3(DPwh);
DPwh4 =lag4(DPwh);
DPct = LPct - LPct1;
DPct1 =lag(DPct);
DPct2 =lag2(DPct);
DPct3 =lag3(DPct);
DPct4 =lag4(DPct);
DPe = LPe - LPe1;
DPe1 = lag(DPe);
DPe2 = lag2(DPe);
DPe3 = lag3(DPe);
DPe4 = lag4(DPe);
run;

/*monthly ARDL Model for the reduced feed price*/

/* Lagrangine Multilier Test, AIC, BIC*/
proc autoreg data = Work.SAEA;
title "Reduced Feed Price: ARDL(lag0)";
model  DPfeed =  DPfeed1 DPf DPco  DPso DPct DPe
              LPfeed1 LPf1 LPco1 LPso1 LPct1 LPe1/ godfrey
              lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPfeed1=0,  LPf1=0, LPco1=0,  LPso1=0,  LPct1=0, LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Feed Price: ARDL(lag1)";
model  DPfeed =  DPfeed1 DPf DPf1 DPco DPco1  DPso  DPso1 DPct  DPct1
              DPe DPe1 LPfeed1 LPf1 LPco1 LPso1 LPct1 LPe1/ godfrey
              lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPfeed1=0,  LPf1=0, LPco1=0,  LPso1=0,  LPct1=0,   LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Feed Price: ARDL(lag2)";
model  DPfeed =  DPfeed1 DPfeed2 DPf DPf1 DPf2  DPco DPco1 DPco2  DPso
              DPso1 DPso2 DPct DPct1 DPct2  DPe DPe1 DPe2 LPfeed1
              LPf1 LPco1 LPso1 LPct1 LPe1/ godfrey lagdep = DPfeed1
              method = uls;
/*test for the cointegration:F test*/
test LPfeed1=0,  LPf1=0, LPco1=0,  LPso1=0,  LPct1=0,  LPe1=0;
```

```
run;

proc autoreg data = Work.SAEA;
title "Reduced Feed Price: ARDL(lag3)";
model  DPfeed =  DPfeed1 DPfeed2 DPfeed3 DPf DPf1 DPf2 DPf3  DPco DPco1
               DPco2 DPco3 DPso  DPso1 DPso2 DPso3 DPct DPct1 DPct2
               DPct3 DPe DPe1 DPe2 DPe3 LPfeed1 LPf1 LPco1 LPso1
               LPct1 LPe1/ godfrey lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPfeed1=0,  LPf1=0, LPco1=0,  LPso1=0,  LPct1=0,  LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Feed Price: ARDL(lag4)";
model  DPfeed =  DPfeed1 DPfeed2 DPfeed3 DPfeed4 DPf DPf1 DPf2 DPf3
               DPf4 DPco DPco1 DPco2 DPco3 DPco4 DPso  DPso1 DPso2
               DPso3 DPso4 DPct DPct1 DPct2 DPct3 DPct4 DPe DPe1 DPe2
               DPe3 DPe4 LPfeed1 LPf1 LPco1 LPso1 LPct1 LPe1/ godfrey
               lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPfeed1=0,  LPf1=0, LPco1=0,  LPso1=0,  LPct1=0, LPe1=0;
run;


/*Feed Price: long run relationship*/
proc reg data = Work.SAEA;
title "Feed Price: long run relationship";
model  LPfeed1 =  LPf1 LPco1 LPso1 LPct1 LPe1;
output out = feedprice  R = feedresidual;
run;

/* Lagrangine Multilier Test, AIC, BIC*/
proc autoreg data = feedprice;
title "Reduced Feed Price: ARDL(final test)";
model  DPfeed =  DPfeed1 DPf DPf1  DPco DPco1 DPso DPso1 DPct DPct1 DPe
               DPe1 feedresidual/ godfrey  lagdep = DPfeed1
               method = uls;
run;


proc reg data = feedprice;
title "Reduced Feed Price: ARDL(lag1)";
model  DPfeed =  DPfeed1 DPf DPf1  DPco DPco1 DPso DPso1 DPct DPct1
               DPe DPe1 feedresidual;
run;
```

```
/*ARDL Model:reduced form equation for catfish farm price*/

/*create datafile*/
libname New1 'C:\Documents and Settings\agecon\Desktop\Thesis\Thesis';

/*monthly data*/
proc import out = Work.SAEA
DATAFILE = "C:\Documents and Settings\agecon\Desktop\Thesis\
Thesis\Catfishfarm_correction.xls"
 DBMS=EXCEL REPLACE;
SHEET = "monthly";
 GETNAMES=YES;
    MIXED=NO;
    SCANTEXT=YES;
    USEDATE=YES;
    SCANTIME=YES;
run;

/*create log terms*/
data Work.SAEA;
set Work.SAEA;
LPf = log(Pf);
LPfeed = log(Pfeed);
LPp = log(Pp);
LPe= log(Pe);
LLPfeed = lag18(LPfeed);
LPfeed = LLPfeed;
run;

/*create lag terms*/
data Work.SAEA;
set Work.SAEA;
LPf1 = lag(LPf);
LPp1 = lag(LPp);
LPfeed1 = lag(LPfeed);
LPe1= lag(LPe);
run;

/*create difference terms*/
data Work.SAEA;
set Work.SAEA;
DPf = LPf - LPf1;
DPf1 = lag(DPf);
DPf2 = lag2(DPf);
DPf3 = lag3(DPf);
DPf4 = lag4(DPf);
DPp = LPp - LPp1;
DPp1 =lag(DPp);
DPp2 =lag2(DPp);
DPp3 =lag3(DPp);
DPp4 =lag4(DPp);
DPfeed = LPfeed - LPfeed1;
DPfeed1 = lag(DPfeed);
DPfeed2 = lag2(DPfeed);
DPfeed3 = lag3(DPfeed);
DPfeed4 = lag4(DPfeed);
```

```
DPe = LPe -LPe1;
DPe1 =lag(DPe);
DPe2 =lag2(DPe);
DPe3 =lag3(DPe);
DPe4 =lag4(DPe);
run;

/*monthly ARDL Model for the reduced catfish farm price*/

/* Lagrangine Multilier Test, AIC, BIC*/
proc autoreg data = Work.SAEA;
title "Reduced Catfish Farm Price: ARDL(lag0)";
model  DPf = DPf1  DPp DPfeed DPe LPf1  LPp1  LPfeed1 LPe1/ godfrey
           lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Catfish Farm Price: ARDL(lag1)";
model  DPf = DPf1  DPp  DPp1   DPfeed DPfeed1  DPe DPe1  LPf1  LPp1
           LPfeed1 LPe1/ godfrey lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Catfish Farm Price: ARDL(lag2)";
model  DPf = DPf1 DPf2  DPp  DPp1  DPp2  DPfeed DPfeed1 DPfeed2
           DPe DPe1 DPe2 LPf1  LPp1  LPfeed1 LPe1/ godfrey
           lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Catfish Farm Price: ARDL(lag3)";
model  DPf = DPf1 DPf2 DPf3  DPp  DPp1  DPp2  DPp3  DPfeed
           DPfeed1 DPfeed2 DPfeed3 DPe DPe1 DPe2 DPe3  LPf1
           LPp1  LPfeed1 LPe1/ godfrey lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;
run;

proc autoreg data = Work.SAEA;
title "Reduced Catfish Farm Price: ARDL(lag4)";
model  DPf = DPf1 DPf2 DPf3 DPf4  DPp  DPp1  DPp2  DPp3  DPp4
           DPfeed DPfeed1 DPfeed2 DPfeed3 DPfeed4
           DPe DPe1 DPe2 DPe3  DPe4  LPf1  LPp1  LPfeed1 LPe1/godfrey
           lagdep = DPfeed1 method = uls;
/*test for the cointegration:F test*/
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;
run;
```

```
/*Catfish Farm Price: long run relationship*/
proc reg data = Work.SAEA;
title "Farm Price: long run relationship";
model  LPf1=  LPp1  LPfeed1 LPe1;
output out = farmprice  R = farmresidual;
run;

proc autoreg data=Work.SAEA;
model  DPf =  DPf1 DPp DPp1 DPfeed  DPe LPf1  LPp1  LPfeed1 LPe1/
            godfrey lagdep = DPfeed1 method = uls;
test LPf1=0, LPfeed1=0, LPp1=0, LPe1=0;

/* Lagrangine Multilier Test, AIC, BIC*/
proc autoreg data = farmprice;
title "Reduced Catfish Farm Price: ARDL(lag0)";
model  DPf =  DPf1 DPp DPp1 DPfeed  DPe farmresidual/ godfrey
            lagdep = DPfeed1 method = uls;
run;

proc reg data = farmprice;
title "Reduced Feed Price: ARDL(lag1)";
model  DPf =  DPf1 DPp DPp1 DPfeed  DPe farmresidual;
run;
```