From The Gas Pump To Our Hips: The Impact That U.S. Corn-Ethanol Production Has On America's Obesity Epidemic

by

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Abstract

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The purpose of this study is to examine the effect that increased U.S. corn-ethanol production has on food prices and, in turn, the diet choices of the U.S. population.

Previous literature has confirmed the linkages between the energy market and the corn market and has separately examined the relationship between relative food prices and obesity. The purpose of this study is to link ethanol production to obesity.

The first two sections of the model will utilize various econometric techniques to test the existence of certain empirical relationships over the period of January 1982-May 2011. The final stage will employ ordinary least squares regression analysis using data from 1995-2010. The data included has been collected from BLS, USDA, CDC, and *The Economist*. The empirical testing for the final part of model uses annual data for only 16 observations, which may reduce the validity of the test.

I anticipate that increased U.S. corn ethanol production will lead to higher corn prices, and thus higher prices for "unhealthy" foods. To the extent that people respond to relative prices, I would expect a shift in consumption from "unhealthy" foods towards "healthy" foods, thus slowing down America's obesity problem.

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Acknowledgements

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Chapter 1

Introduction

The market for U.S. corn-ethanol has undergone substantial changes in the past decade. While the technology for ethanol has existed since the 1980's, both an energy demand crisis and government legislation have created a surge in ethanol production in the mid-2000's. Recent transformations in the domestic ethanol market have now made America the world's largest producer of ethanol, responsible for 52% of total global production (Serra et al, 1).

Whereas other ethanol producing countries use sugarcane to produce ethanol (for example, Brazil), the vast majority of ethanol produced in the United States is corn derived. Ethanol's rising demand has contributed to historically high corn prices in recent years. Corn has long been a foundational crop to America's food industry and currently stands as the most subsidized crop in the U.S. Given corn's role as both a cellulosic feedstock and a versatile food input, recent changes in the ethanol industry have had a substantial impact on America's food market.

Independent from changes in the ethanol industry, the U.S. has developed into the world's most obese country. Finkelstein and Zuckerman (2008) argue that relative prices of "healthy" and "unhealthy" foods have contributed to the growing number of obese Americans. The work of Serra et al. (2010) indicates that the recent ethanol boom has tightened the linkage between energy and food markets. To this extent, we would then expect a tighter relationship between ethanol and food prices, therefore influencing consumer diet choices. Ethanol's interaction among various markets has led us to study the following question: “Does an increase in U.S. corn-ethanol production have a beneficial impact on the America’s obesity epidemic.”

Given corn’s larger presence in foods categorized as “unhealthy”, we expect that the recent ethanol boom has caused “unhealthy” foods to become more expensive relative to “healthy” foods. Thus, to the extent that people respond to relative food prices, we would expect consumption to shift away from “unhealthy” foods and towards “healthy” foods, thereby slowing the rate at which America’s obese population is increasing.

Existing literature has separately examined the effects that ethanol production has on food prices and that food prices have on obesity. This study is unique in that it bridges the gap between ethanol production and obesity. Moreover, this study examines the effect that ethanol has certain types of food, whereas other studies examine food prices as a whole.

In the following chapter, an extensive overview is provided that presents the economic and political conditions pertinent to the nature of this study. In the third chapter, we define our analytical approach and discuss the econometric tools being utilized. Chapter 4 will present and analyze our empirical findings. The final chapter will conclude our study and discuss sources of error and policy implications.

Chapter 2

Overview and Review of Existing Literature

2.1 The Global Energy Crisis

In recent years, the global economy has faced an increasingly severe energy crisis. The U.S. Petroleum Council highlights the severity of our situation. "Since oil was discovered 125 years ago, 1 trillion barrels have been consumed. By 2030, an additional 1 trillion barrels of oil are expected to be needed" (National Petroleum Council). In essence, the global economy will need as much oil in the next 20 years as has been consumed in the entirety of oil's history. It is for this reason that energy prices are at historic highs, as represented by the spike in gas prices in 2008 to over $4.00 per gallon. As global oil supply, the world's conventional energy source, struggles to keep with up with energy demand, politicians and energy corporation executives alike are searching for new, viable methods to curb our dependence on foreign oil and oil resources in general. In light of this, energy corporations are not only improving existing oil production methods, but are investing in a number of new alternative energy technologies. Given the crisis at hand, in addition to the escalating outcry against global warming, ethanol fuel has become a popular candidate to help lessen the need for non-renewable oil resources.

2.2 The Ethanol Market

Ethanol as a Fuel Additive

Ethanol, a liquid biofuel, is produced from the fermentation of the sugars found in corn, sugarcane, or soybeans. The most popular type of ethanol in the United States is corn-based ethanol and it serves as an oxygenate that is blended with gasoline. “Oxygenates are required in gasoline to increase the oxygen content, resulting in more complete combustion and, in turn, a reduction in pollutants” (Anderson and Coble, 2010, 51). In 1979, a substance called methyl tertiary-butyl ethyl, or MTBE, replaced lead as an octane enhancer in gasoline (Cancer Society, 2011). In 1990, the United States government passed the Clean Air Act of 1990, which mandated a minimum of 2% oxygen content by weight in all produced gasoline (Cancer Society, 2011). Resulting from this legislation, MTBE became increasingly present in American motor vehicles. However, due to MTBE’s unusually high solubility, it found its way into public water supplies across the country. MTBE’s carcinogenic properties have led to its gradual phasing out in favor of ethanol (Anderson and Coble, 2010, 52). As of 2003, 16 states have banned or restricted the use of MTBE, accounting for a 45% decrease in consumption (Status of MTBE, 2003).

Ethanol is a safe, non-toxic substitute for MTBE, which has caused a significant decrease in the consumption of MTBE and a proportional increase in ethanol consumption. The effects of this occurrence are illustrated in Figure 1.1.

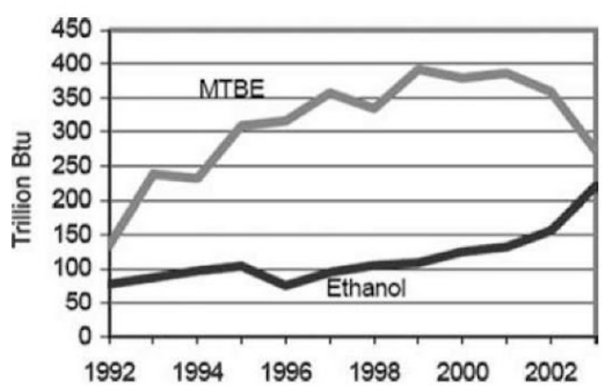

Figure 2.1: Ethanol and MTBE Consumption in the Transportation Sector, 1992-2003
(Source: Alternative Energy Technologies: Price Effects)

The vast majority of vehicles in the United States operate on gasoline that is blended with 10% ethanol (E10). Every state in the U.S. sells gasoline that is blended with ethanol, although only a handful of states have mandates that require E10 to be sold at gas stations. Ethanol even has the potential to act as a major fuel source in gasoline that contains 85% ethanol (E85). Be that as it may, it requires a special engine that is compatible with E85, and only 6 million of America's 237 million car fleet operate on E85 (Luchansky and Monks, 2008, 2). Due to ethanol's renewability and its potential as a non-toxic, clean burning energy source, it has gained significant popularity in recent years.

Demand for Ethanol, Legislation

Numerous factors have influenced ethanol's status in the U.S. energy market, not the least of which has been government legislation over the past decade.

As previously mentioned, state regulations have enabled ethanol to become the preferred fuel additive in the United States. Beginning in 2002, the United States Congress began the Renewable Fuels Standard (RFS), under which were a series of mandates that "essentially specified the volume of renewable fuels that refiners are required to blend with their petroleum-based fuels" (Anderson and Coble, 2010, 49). The first of which was the Energy Policy Act of 2002 that originally called for the production of 3.5 billion gallons of renewable fuels by 2008. The Act was revised in 2005 and 2007, which called for 5.4 and 9.0 billion gallons respectively, an increase of 67% in just 2 years (Anderson and Coble, 2010, 51). The effects of the aforementioned mandates have translated into a significant increase in the demand for ethanol over the past ten years.

Production of Ethanol

Historically high energy prices, coupled with the spike in ethanol demand, has made ethanol a more profitable commodity, giving ethanol producers an incentive to increase supply. There are currently 120 ethanol plants in operation in the U.S., and an additional 76 plants are being expanded or built (Luchanksy and Monks, 2008, 2). Ethanol plant expansion throughout the U.S.'s Corn Belt is likely to bring ethanol production capacity to 11 billion gallons in 2011 (Luchansky and Monks, 2008, 2). In 2007, the U.S. produced 6.2 billion gallons of corn-based ethanol and the Energy and Security Act of 2007 calls for 36 billion gallons of renewable transportation fuels by 2022, 16 billion of which are to be made from cellulosic feedstocks (Harrison, 2009, 493). Of these 16 billion gallons of required biofuels, no more than 15 billion gallons can come from ethanol (Harrison, 2009, 493).

The production of ethanol is becomingly increasingly more efficient with the development and implementation of new technologies. Conventional ethanol production methods fail to utilize the fiber portion of the corn kernel. New technologies have enabled the fermentation of the fiber fraction, increasing the ethanol yield per bushel of corn by roughly 10-13% (Cooper, 3). Furthermore, corn hybrids are being engineered specifically for the use of ethanol production. These new hybrids contain higher levels of starch and are expected to increase ethanol yields by 3-5% per bushel of corn (Cooper, 3). Increased corn yields coupled with the application of these technologies has the ability to dramatically increase ethanol production without significantly altering corn acreage (Cooper, 3).

Elasticity

The work of Luchansky and Monks (2008) aims to quantify the supply and demand sides of the ethanol market at the national level. Monthly data from 1997-2006 is used in a two-stage least squares model. The supply and demand equations are summarized below:

$$\text{Supply: } Q_{ethanol} = f(P_{ethanol},\ P_{corn}, P_{cornoil}, \text{trend})$$

$$\text{Demand: } P_{ethanol} = f(Q_{ethanol}, P_{gas}, \text{\# vehicles, pop. of states banning MTBE}, P_{MTBE})$$

The supply equation above states that the quantity of ethanol that is produced is determined by the market price of ethanol, the price of corn, the price of corn oil (a co-product of ethanol) and "trend," a simple linear monthly term. The demand equation states that the price of ethanol is determined by the quantity of ethanol produced, the price of gasoline, the number of vehicles there are in the U.S., the number of states that ban the use of MTBE and the price of MTBE. The natural log of each variable was taken in order to produce a double-log model. This model is useful, for the regression coefficients yield direct estimates of the elasticities.

In accordance with Serra et al. (2010) and Fortenbery and Park (2008), this article finds that "Corn prices are found to be positively and significantly influenced by ethanol output. As ethanol production increases, the price of corn rises" (Luchansky and Monks, 2008, 7). The results state that ethanol supply has a price elasticity of 0.237, indicating that ethanol supply is inelastic in the short run (Luchansky and Monks, 2008, 7). This value implies that it is difficult for ethanol producers to change production in response to changes in ethanol prices. Considering the large plants required to produce ethanol, it makes sense that ethanol supply is price inelastic. Conversely, ethanol demand is found to be price elastic (-1.605 to -2.915). That is, the quantity of ethanol demanded is very responsive to changes in ethanol prices.

Another interesting finding from the demand equation regards the price elasticity of gasoline, which was estimated to range from -2.080 to -3.606 (Luchanksy and Monks, 2008, 8). These findings suggest "a 1% increase in gasoline prices corresponds with a 2% to 3.6% decrease in the quantity of ethanol demanded" (Luchanksy and Monks, 2008, 8). Given ethanol's primary role as a fuel additive in blended gasoline, the two commodities are complements, and therefore, it makes sense that their prices are highly correlated.

As these results prove, ethanol is still far from being a viable alternative to gasoline on a large, commercial scale. As Luchansky and Monks (2008) point out, this is true for two reasons. The first of which is the cost of production. "When state and federal subsidies for corn and ethanol production are added together, the subsidy totals more than $7/ bushel of corn per $2.59/ per gallon of ethanol" (10). On an unsubsidized gallon-to-gallon price basis, ethanol can simply not compete with gasoline. The other reason is energy efficiency. "Ethanol only provides about two-thirds the energy of an equal volume of gasoline, so 1.5 gallons of ethanol are necessary to travel the same distance allowed by the use of 1 gallon of gasoline" (10). The work of Luchansky and Monks (2008) provide a deeper understanding of the ethanol market by calculating the relative price elasticities.

Anderson and Coble (2010) study the impacts that the renewable fuels standard (RFS) has on the market for corn. RFS mandates were originally established in the Energy Policy Act of 2002. Revisions to the Energy Policy Act in 2005 and 2007 have continued to increase the levels of minimum ethanol production, yet ethanol production remains elevated above those mandates. Anderson and Coble (2010) examine the effect of a possible removal of government mandates as they aim to "model price discovery in the corn market, accounting for the impact of RFS mandates on expectations related to corn supply and demand" (Anderson and Coble, 2010, 50).

RFS mandates specify the volume of renewable fuels that must be blended with gasoline. Since ethanol output cannot fall below the mandated level, Anderson and Coble (2010) argue that ethanol-derived corn demand below this level should be very inelastic. This is because there are few substitutes for ethanol that would be able to meet the mandated level of renewable fuels. At levels above the mandated amount, corn demand for ethanol is subject to a full range of market forces, and thus, is presumed to be price elastic. Graphically, this would appear as a kinked demand curve at the mandated level of ethanol. In essence, the key factor influencing the market is where the mandated level is relative to the actual level of production. The closer that actual production is to the mandated level, the larger the impact that the mandate will have on production. Conversely, production levels that are far away from the mandated level are hardly affected by the mandate.

Similar to the objectives of Luchansky and Monks (2008), Anderson and Coble (2010) use elasticities for the components of corn demand to provide a deeper understanding of the market. Much like Luchanksy and Monks (2008), Anderson and Coble (2010) break down the demand for corn into three categories, feed, exports, and ethanol (FAI). The results show that under the current mandates, any reduction in corn supply will be met by an inelastic demand response from the ethanol sector, taking corn's use away from other sectors. Furthermore, the mandate leads to higher equilibrium prices and quantities compared to that of a mandate-free regime.

The work of the aforementioned authors provides considerable insight into the dynamics of the corn and ethanol markets. Their work provides strong evidence that the ethanol boom of the second half of the 2000's has led to considerably higher corn prices. We now look at the impact that higher corn prices have on the market for food.

Linkage Between Food and Energy Markets

Linkages between the market for food and the market for energy occur primarily through the market for corn. Corn's versatility as both an edible food product and a cellulosic feedstock allows for this transition between markets.

Serra et al. (2010) examine the relationship between fuel and food markets in the U.S. from 1990-2008. The period was chosen given the significant change that was experienced in the U.S. ethanol and related markets at the time. The article examines the relationship between monthly ethanol, corn, oil, and gasoline prices using a co-integration (smooth error transition vector model). A number of factors are likely to affect the market for ethanol, and thus, nonlinear price changes in the ethanol market are likely to occur. In order to capture these nonlinearities the smooth transition vector error correction model was chosen. By using the chosen model, the authors aim to capture the magnitude, timing, and duration of the individual price shocks on the market.

Serra et al. (2010) separate their work from that of the existing literature by allowing for nonlinear price adjustments in the U.S. ethanol market. The literature reveals that a strong link between the corn and energy markets is present. This link occurs primarily through the ethanol market, which helps to explain the dramatic corn price increase during the ethanol boom beginning in the mid 2000's. Serra et al. (2010) report, "that large corn price increases in the second half of the 2000's were, at least partially, due to the expansion of the ethanol industry" (42). This finding is consistent with the work of Wallander et al. (2011) and Luchansky and Monks (2008), who both suggest that ethanol's production is struggling to keep up with demand, thereby driving higher corn prices. Thus, the ethanol boom of the latter half of the 2000's has been determined to cause higher corn prices since that time. While this may be true in recent years, historically it has been corn prices that cause ethanol prices. This makes sense considering corn is the primary input of ethanol production. The results produced by Serra et al. (2010) suggest that energy markets can drive food prices up. In the concluding remarks, the authors point out that the U.S. ethanol industry is amidst a transitional period, and future research is necessary in order to determine if the derived results will hold up over time.

The work of Fortenbary and Park (2008) differs slightly from that of Serra et al. (2010). The focus of the work of Fortenbary and Park (2008) is to analyze the effect of each category of corn demand on the U.S. corn price. They break the demand for corn into feed, export, and food alcohol and industrial use (FAI). "Currently, about half of the FAI demand goes to the production of ethanol" (Fortenbary and Park, 2008, 6). The model consists of a system of equations that represent corn supply and the three components of corn demand that were mentioned previously. The price of corn is estimated using three-stage least squares. The data used in the estimations spans an 11-year period, ranging from 2nd quarter 1995 to 1st quarter 2006. The dataset is structured to coincide with the marketing year for U.S. corn, which begins in September when the corn is harvested.

The results of the study indicate that corn prices are most heavily influenced by the FAI component of corn demand. “Export consumption has the second greatest impact and feed consumption follows. Thus, growth in ethanol production is important in explaining corn price determination” (Fortenbary and Park, 2008, 13). This finding is consistent with the results found by Serra et al. (2010) that corn price inflation is a result of increased ethanol production. While the methodology of this study differs from that of previous studies, there remains substantial evidence in the literature that the recent boom in ethanol production has driven up the price of corn.

2.3 The Market for Corn

The demand for corn can be broken down into four components: food, feed for livestock, exports, and ethanol. As Figure 2.2 represents, the non-ethanol uses of corn have not altered significantly over the past decade, as greater ethanol production has taken over a larger portion of total corn production (Wallander et al, 2011, 3).

The rise in ethanol production has had significant impacts on the market for corn. In 2007, U.S. farmers planted 93.6 million acres of corn, the largest planting of corn since 1944 (Harrison, 2009, 493). The increase in corn planting is largely in response to increased ethanol production. “Between 2000 and 2009, corn used for ethanol increased by 3.7 billion bushels, while total corn production increased by 3.2 billion bushels” (Wallander et al, 2011, 3). The increase in corn yields have not kept up with the growth of ethanol production, creating a shortage. As a result, corn has exhibited historically high prices in recent years. In the 2007/ 2008 marketing years for corn, the farm level price for corn averaged between $4.10-4.50 per bushel, a historic high (Harrison, 2009, 493). “The increasing demand for ethanol requires the use of large amounts of corn, soybeans, sugarcane, or other crops to feed the large fermentation vats necessary for mass production of ethanol fuel. The need for corn to produce much larger quantities of ethanol has inflated prices from the generally stable price of $2 per bushel to more than $4 by early 2007” (Luchansky and Monks, 2008, 2). Despite historically large corn acreage and continuous advancements in corn yields, the surge in ethanol production has increasingly taken corn away from its other, non-ethanol uses. As of 2002, ethanol accounted for about 10% of total corn use (Anderson and Coble, 2010, 53). In 2007, this percentage increased to 24% (Harrison, 2009, 493), and in 2009 this figure was estimated to be around 30% (Anderson and Coble, 2010, 53). The proportion of corn use devoted to ethanol production is increasing rapidly, while concurrent levels of non-ethanol corn use have remained stable or declined, with the most notable decline in the feed component (Anderson and Coble, 53). Corn’s use as feed for livestock has historically been the largest component of corn’s demand. As ethanol production has been chipping away from the corn devoted to feeding America’s livestock, meat and other livestock products are becoming more expensive to produce.

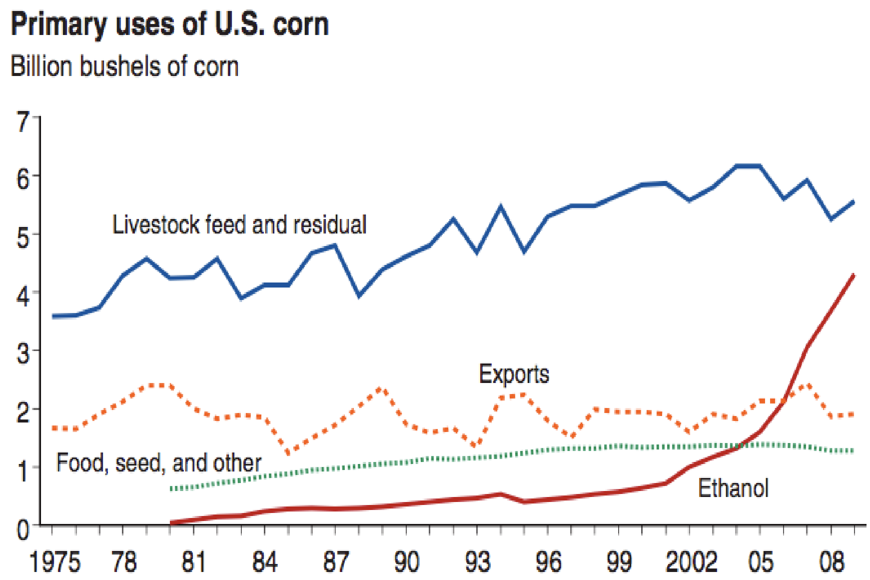

Figure 2.2: Primary Uses of U.S. Corn, 1975-2009
(Source: U.S. Department of Agriculture)

Corn as a Food Source

Corn plays a major role in the United States food market. In 1973, U.S. Secretary of Agriculture, Earl "Rusty" Butz, revolutionized the American agriculture industry in such a way that would establish "cheap corn" for decades to come (Pollan, 2006, 53). With an abundance of cheap corn available, American food scientists would devise unique ways to incorporate corn into our everyday diets.

Corn serves multiple purposes as a food source. The most obvious role that corn plays as a food source is simply eating corn itself, although there are numerous other ways that corn may find its way onto the dinner table. Corn is frequently transformed into a handful of "food inputs", the most common of which are cornstarch, corn syrup, and high-fructose corn syrup. These goods produce a cheap dose of pure sweetness and fat, and are commonly used in soft drinks and various junk foods (Duckworth, 2012, 1). Lastly, the most indirect method that corn is transformed into food is as feed for cattle, pigs, and chickens. Being that corn prices have reached historically high levels, producers of America's meat supply have now passed on higher prices to consumers. Corn has become such a large presence in America's food industry that Michael Pollan (2006) estimates that of the forty-five thousand items in the average American supermarket, more than a quarter of them now contain corn (19). Given our reliance on corn as a food source, we can expect that higher corn prices lead to food price inflation.

Harrison (2009) examines the "effects of biofuel production on commodity prices and their transmission to retail food prices" (493). Much like Anderson and Coble (2010), Serra et al. (2010), and Fortenbery et al. (2008) have all discussed in their findings, the increased demand for corn-ethanol has affected corn prices in recent years. Corn serves as feed for numerous commercial livestock and as an input in a several food products, and therefore, we can expect that higher corn prices are likely to have some effect on the retail food prices. Harrison (2009) cites a previous study that estimates that a "30% increase in the price of corn, and associated increases in the prices of wheat and soybeans, would increase egg prices by 8.1%, poultry prices by 5.1%, pork prices by 4.5%, beef prices by 4.1%, and milk prices by 2.7%" (499). The findings discussed by Harrison imply that price inflation for the aforementioned food items are the result of increased ethanol production due to higher oil prices. Harrison's discussion is consistent with that of related literature.

2.4 Obesity in America

America currently stands as the world's most obese country, with roughly two-thirds of Americans classified as either overweight or obese (Finkelstein and Zuckerman, 2008, xi). This onset of obesity has taken hold over the past three decades; the number of obese individuals has more than doubled during this time (Finkelstein and Zuckerman, 2008, xi). Obesity increases the risk of a number of medical conditions (i.e. Type II diabetes, hypertension, and high cholesterol) (Finkelstein and Zuckerman, 2008, 10). In fact, poor diet and physical inactivity attributes to 15.2% of total U.S. deaths, the second leading cause of death behind tobacco (Finkelstein and Zuckerman, 2008, 10). Given the severity of obesity in America, the study of its causes and implications are worthwhile.

Finkelstein and Zuckerman (2008) argue that America's economic growth is the root cause of this problem, as technology has enabled lifestyles that are more sedentary and our nation's food industry increasingly allows us to consume more for our dollar. Since 1982, healthy foods such as fruits and vegetables have become increasingly more expensive relative to unhealthy foods such as fast food and junk food. Junk foods are appealing to many people as they are a quick and immediate source of calories, although not necessarily rich with nutrients. On the other hand, healthy foods such as fruits and vegetables are high in nutrients, but have fewer calories. As corn acreage expands to accommodate for increased ethanol production, the supply of fruits and vegetables is likely to decline, thus raising prices. However, given corn's extensive use as a food input, ethanol production is expected to have a larger impact on the prices of "unhealthy foods" relative to that of "healthy foods".

2.5 Summary

In an effort to help diversify America's energy sources and decrease our dependence on finite fossil fuels, government mandates have greatly influenced the dramatic increase of ethanol fuel production over the past decade. The existing literature provides ample reason to believe that a surge in ethanol production has contributed to higher food prices in recent years. That being said, the analysis of this paper will examine which *types of food* have been affected most by the evolution of the ethanol market. We will look at the magnitude of relative price changes and its relationship to obesity. The next chapter will provide an outline of our analytical approach and discuss the econometric techniques used in our model.

Chapter 3

Econometric Techniques and Analytical Approach

This chapter begins with a detailed description of the approach we are using to answer the question at hand. Given the various markets at play, our analytical approach will be broken into three stages. Stage 1 will analyze the effects that ethanol production has on corn prices. Stage 2 will test the relationship between corn prices and the relative prices of "more" and "less" healthy foods as defined by Finkelstein and Zuckerman (2008). The final stage will assess the effects that relative food prices have on obesity. Stages 1 and 2 will utilize cointegration techniques, supplemented by Granger causality tests. Stage 3, due to data limitations, will utilize ordinary least squares regression analysis. The purpose of this chapter is to outline the reasons supporting this multiple-stage model and provide an understanding of the econometric tools that being utilized.

3.1 Methodology

Time series data, like the data used in this study, are an important type of data that are used regularly in economic analysis. Nevertheless, there are several obstacles to be overcome when testing relationships between two or more time series variables.

One overarching problem when running regressions involving time series data is that the assumption has been made that the underlying data are stationary (Gujarati, 2003, 792). That is, the data are assumed to have a mean and variance that do not vary systematically over time (Gujarati, 2003, 26). Many time series data (e.g. GDP), exhibit a clear upward trend so to assume that the data are stationary naturally lends itself to some problems. The main problem that we are concerned with in this study is that of spurious regression results, in which two or more variables may exhibit a significant relationship where in fact the relationship is due to some exogenous factor. One technique that can protect against spurious results is cointegration. Much like the work of Serra et al. (2010), we will utilize cointegration testing in order to establish the existence of a long run relationship between our chosen variables.

Cointegration

Cointegration testing will serve as the primary method of testing for significant long run relationships in this analysis. By definition, "cointegration is a statistical property of time series data in which two or more time series each share a certain type of behavior in terms of their long run fluctuations" (Swedish Academy of Sciences). More specifically, cointegration tests hypotheses and estimates relationships among *nonstationary variables*. A variable is said to be nonstationary if it has no clear tendency to return to a constant value or fluctuates around a linear trend (Swedish Academy of Sciences). This phenomenon of nonstationarity may also be referred to as *random walk*. Equation 1 below exhibits the random walk model.

$$Y_t = Y_{t-1} + u_t \qquad \textbf{(1)}$$

In this model, "suppose u_t is a white noise error term with mean 0 and variance σ^2. The equation states that the series Y_t is said to be a random walk if the value of Y at time t is equal to its value at time $(t-1)$ plus a random shock" (Gujarati, 2003, 799). We can further think of this equation as a regression of Y at time t on its value lagged one observation period (Gujarati, 2003, 799). This lag in the random walk model makes the cointegration technique very data intensive. Due to data limitations regarding obesity measures, cointegration will only be used in Stages 1 and 2 of our analytical approach.

It is common for time series variables, such as the ones used in this analysis, to develop stochastically, thus exhibiting random walk. The cointegration technique is useful in that it protects against spurious results that ordinary least squares (OLS) regression is susceptible to when using nonstationary variables. In an attempt to establish cointegrating relationships in this paper, the methodology will be broken into two steps. Step 1 will verify that each time series being analyzed is, in fact, nonstationary. Step 2 is the performance of the cointegration test itself.

Step 1: The Unit Root Test

The unit root test is a popular test to determine stationarity, or in our case, nonstationarity. To determine whether a time series is nonstationary, we can re-write our random walk model from Equation 1 as

$$Y_t = \rho Y_{t-1} + u_t \qquad -1 \leq \rho \leq 1 \qquad \textbf{(2)}$$

where u_t is a white noise error term and ρ is the coefficient of autocorrelation.

We know that if $\rho = 1$, that is, in the case of a unit root, then Equation 2 becomes the same random walk model as Equation 1, which we know exhibits a nonstationary process (Gujarati, 2003, 814). For testing purposes, we manipulate Equation 2 by "subtracting Y_{t-1} from both sides of the equation to obtain:

$$Y_t - Y_{t-1} = \rho Y_{t-1} - Y_{t-1} + u_t$$

$$= (\rho - 1)\, Y_{t-1} + u_t$$

$$\Delta\, Y_t = \delta\, Y_{t-1} + u_t \qquad \textbf{(3)}$$

where $\delta = (\rho - 1)$ and Δ is the first difference operator" (Gujarati, 2003, 814). In the case that $\delta = 0$, Equation 3 will become

$$\Delta\, Y_t = (Y_t - Y_{t-1}) = u_t \qquad \textbf{(4)}$$

in which case the first differences of a random walk time series model are equivalent to the error term, which we know is stationary (Gujarati, 2003, 814). In other words, if $\delta = 0$, then $\rho = 1$, and the time series being tested is nonstationary (Gujarati, 2003, 814).

To test for nonstationarity, we must regress the first differences of Y_t onto Y_{t-1} and see if the estimated slope coefficient in this regression (δ) is zero or not (Gujarati, 2003, 814). In other words, we test the null hypothesis that $\delta = 0$ around a 95% confidence interval. If we fail to reject the null hypothesis that δ is zero, then the time series Y_t is nonstationary and we say it is I (1). In order to be eligible for cointegration testing, each time series being considered must be I (1).

Step 2: Cointegration Testing

Once the unit root tests confirms that all variables at hand are *I* (1), we may perform a cointegrating regression. Suppose then that we regress Y_t on X_t as follows:

$$Y_t = \beta_1 + \beta_2 X_t + u_t \tag{5}$$

where β_1 is the intercept, β_2 is the slope coefficient and u_t is the white noise error term.

To determine if Y_t and X_t are cointegrated (i.e. there exists a long run equilibrium relationship between X and Y), the error term, u_t, must be stationary. To do so, we re-write Equation 5 and subject u_t to unit root analysis.

$$u_t = Y_t - \beta_1 - \beta_2 X_t \tag{6}$$

If the error term is stationary, or *I* (0), the difference between the two time series at time *t* will remain relatively stable over time and "the two variables will exhibit a long-term, or equilibrium, relationship between them" (Gujarati, 2003, 822). Graphically speaking, the time series will appear to move together. As Gujarati notes, "this presents an interesting situation, for although Y_t and X_t are individually *I* (1), that is, they have stochastic trends, their linear combination is *I* (0). So to speak, the linear combination cancels out the stochastic trends in the two series" (Gujarati, 2003, 822). This testing of the error term is the fundamental difference between ordinary least squares regression analysis and cointegration regression analysis.

Granger-Causality Test

Once cointegrating relationships are established, the Granger causality test will be used to augment our analysis.

At the heart of econometric analysis lies the motive to determine one variable's dependence on other variables. But as we know, a relationship (or even cointegrating relationship) among variables does not imply causality or direction of influence (Gujarati, 2003, 696). For instance, X may be driving Y to change, but not the other way around. This notion of causality is an important topic when dealing with time series data.

Causality becomes an important issue with time series data simply because time only moves in direction, forward. "That is, if event A happens before event B, then it is *possible* that A is causing B. However, it is not *possible* that B is causing A. In other words, events in the past can cause events to happen today. Future events cannot" (Gujarati, 2003, 696). Suppose we are interested in the direction of causality between two time series, Y_t and X_t. The Granger causality test can then be summarized by the estimation of the following two regressions:

$$Y_t = \sum \alpha_i X_{t-i} + \sum \beta_j Y_{t-j} + u_{1t} \quad \textbf{(7)}$$

$$X_t = \sum \lambda_i X_{t-i} + \sum \delta_j Y_{t-j} + u_{2t} \quad \textbf{(8)}$$

where u_{1t} and u_{2t} are uncorrelated (Gujarati, 2003, 697).

Equation 7 suggests that the current value of Y_t is related to past values of itself as well as values of X_t. The reciprocal of this statement is true for Equation 8. In short, the results will show that X_t causes Y_t if $\Sigma\alpha_I \neq 0$ from Equation 7 and $\Sigma\delta_j = 0$ from Equation 8 when tested for significance. The Granger causality test will play a part in our model as it provides more insightful findings. The econometric methods of this paper have been outlined and we will now turn towards the data that will be used in this study.

3.2 Data

The data used were taken from a number of different sources and come in various time series and units.

Stage 1 of our analytical approach uses monthly corn and ethanol prices as reported by the U.S. Department of Agriculture (USDA). Corn prices are quoted in dollars per bushel and ethanol prices are quoted in dollars per gallon. The time period for the first stage of the model ranges from January of 1982 to May of 2011. This is an appropriate time period since ethanol production remained small throughout the 1980's, exhibited small growth over the 1990's, and then boomed in the mid 2000's. This dataset utilizes the most recent data, and thus, it captures all trends of corn and ethanol prices that are relevant to the purpose of this paper.

Stage 2 uses monthly corn prices, monthly prices of meat products (beef, pork, poultry, and fish) and the monthly prices of "more" and "less" healthy foods. Corn prices were taken from the USDA whereas meat prices and relative food prices are comprised of various consumer price indexes (CPI) taken from the Bureau of Labor Statistics. The CPI indexes for relative food prices have been grouped into the two previously mentioned food categories. "Healthy foods" consists of the non-seasonally adjusted CPI for Fruits and Vegetables, for all urban consumers. "Unhealthy foods" is comprised of the following non-seasonally adjusted CPIs for all urban consumers: Sugars and Sweets, Fats and Oils, Other Foods, and Non-alcoholic Beverages. The index produced by the grouping of these indexes is the sum of a weighted average according to each category's relative importance as of November 2011. The aforementioned classification for "healthy" and "unhealthy" foods was that of Finkelstein and Zuckerman (2008), adjusted slightly due to data availability. The time period for this stage of the model is once again January of 1982 to May of 2011 in order to remain consistent with the first stage of the model.

The final stage will consist of annual prices of meat products, "healthy" and "unhealthy" foods and annual data that report the percentage of the U.S. population with a body mass index (BMI) above 30. "Body mass index is calculated by taking an individual's weight in kilograms divided by height in meters squared (BMI = kg/ m^2)" (Finkelstein and Zuckerman, 2008, 7). A BMI between 30 and 35 is classified as obese, whereas anything over 35 is consider very obese. BMI aims at measuring body fat, and while not completely accurate, it is widely regarded as a reliable proxy. The BMI data was taken from the Center for Disease Control and is only available on an annual basis from 1995-2010. To supplement our analysis, we will also use data regarding the prices of McDonald's "Big Mac" taken from the *The Economist*'s: Big Mac Index.

3.3 Analytical Approach

As previously mentioned, the analytical approach for this study will comprise of three stages. Each stage aims at establishing a particular relationship between two variables. Once the targeted relationship has been verified, we will move on to the next stage of the analytical approach. The ultimate goal of our approach is to examine any existing relationship that U.S. corn ethanol production has with America's obesity epidemic. The analytical approach is segmented as follows:

Stage 1: Ethanol Prices and Corn Prices

Stage 1 will concentrate on the relationship between an increase in U.S. corn ethanol production and U.S. corn prices.

In response to escalating demand in the past decade, ethanol production has nearly doubled between 2002 and 2005 alone (Cooper, 1). However, demand for non-ethanol corn use has remained steady (Cooper, 2). While technological advances have enabled historically high corn yields, it has not been enough to fully meet the needs of the emerging ethanol industry. Consequently, corn is being taken away from its traditional non-ethanol uses in order to fuel ethanol's needy demand. Because the overwhelming majority of U.S. ethanol is derived from corn, we expect that a linkage exist between the two markets. The rising demand for ethanol would trigger a boom in corn demand, ethanol's primary input. Corn's rising demand is exceeding its supply, thus driving higher corn prices (Wallander et al, 2011, 3). A visual depiction of corn and ethanol prices from 1982.01-2011.05 is shown in Figure 3.1. It is interesting to note that since the mid-2000's, corn prices have been on a dramatic upward trend. The timing of this price increase coincides with the ethanol boom.

Given the aforementioned scenario in the U.S. agriculture industry, we would expect a significant long-run relationship to exist between ethanol production and corn prices. Stage 1 of our analytical approach is inspired by the work of Serra et al. (2010) in which cointegrating techniques are used to model the relationships between the prices of corn, ethanol, oil and gasoline. As their results suggests, there is a long-run (cointegrating) relationship between food and energy prices (i.e. corn and ethanol). The purpose of this stage of the model is to reproduce the findings of Serra et al. (2010) and update their work with more recent data. Our cointegration model will use monthly ethanol prices as the independent variable and monthly corn prices as the dependent variable. Note, however, that such cointegrating relationships do not imply causation in any direction. Therefore, in addition to recreating the work of Serra et al. (2010) we will perform the Granger causality test to determine if ethanol production is in fact driving corn higher prices in recent years as the literature suggests. If a cointegrating relationship between ethanol prices and corn prices is confirmed, we will move to Stage 2 of our analytical approach, in which we diverge from the energy industry and focus on the role that corn plays in the U.S. food market.

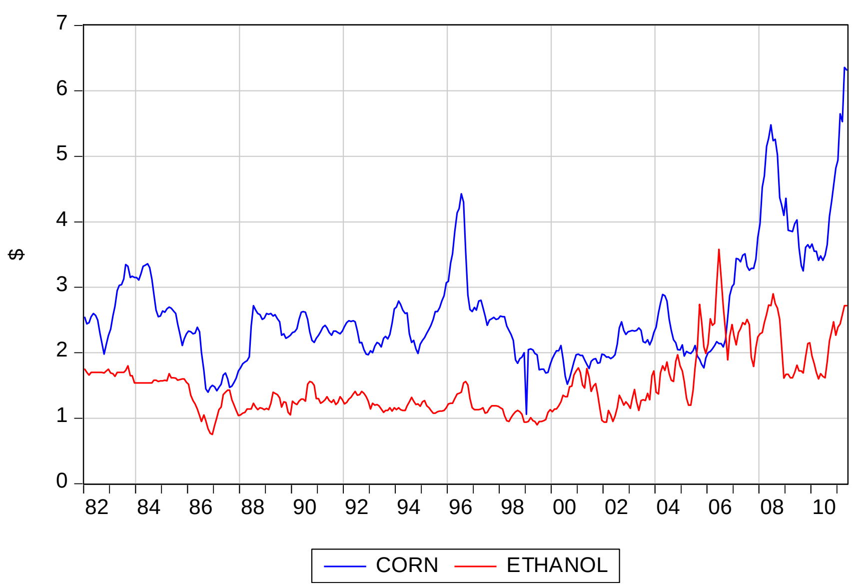

Figure 3.1: Monthly Corn and Ethanol Prices, 1982.01-2011.05
(Source: U.S. Department of Agriculture)

Stage 2: Corn Prices and Food Prices

Stage 2 will examine the effect that corn prices have on both meat prices and relative food prices.

Michael Pollan (2006) reports that about 60 percent of America's corn crop goes to feeding livestock (Pollan, 66). Meat, while high in protein and B-vitamins, contains high levels of fat and cholesterol. Excess consumption of meat has the potential to contribute to obesity. Given corn's integral role in feeding America's livestock, a statistical analysis of their relationship is worthwhile

For several decades now, corn has played an integral role in America's food industry as modern food science has extended corn's breadth far beyond the traditional consumption method of just "corn on the cob". Given corn's presence in the U.S. food market, Stage 2 aims to examine the relationship between corn prices and relative prices of "more" and "less" healthy foods. This stage of the model serves as an intermediate step that links the energy market to America's obesity epidemic.

The work of Finkelstein and Zuckerman (2008) reveals that relative price differences between "more" and "less" healthy foods may have a substantial impact on American obesity figures. That being said, relative food prices are used in this phase of the model as a segue from the corn market to the food market. As Figure 3.2 and Figure 3.3 clearly show, there has been a growing disparity between "healthy" and "unhealthy" foods since the late 1980's.

Fresh fruits and vegetables are typically low in calories, yet they offer consumers with bountiful nutrition in the form of vitamins and minerals. Should Americans choose to engage in a vegetarian diet, they are likely to experience health benefits. It is for this

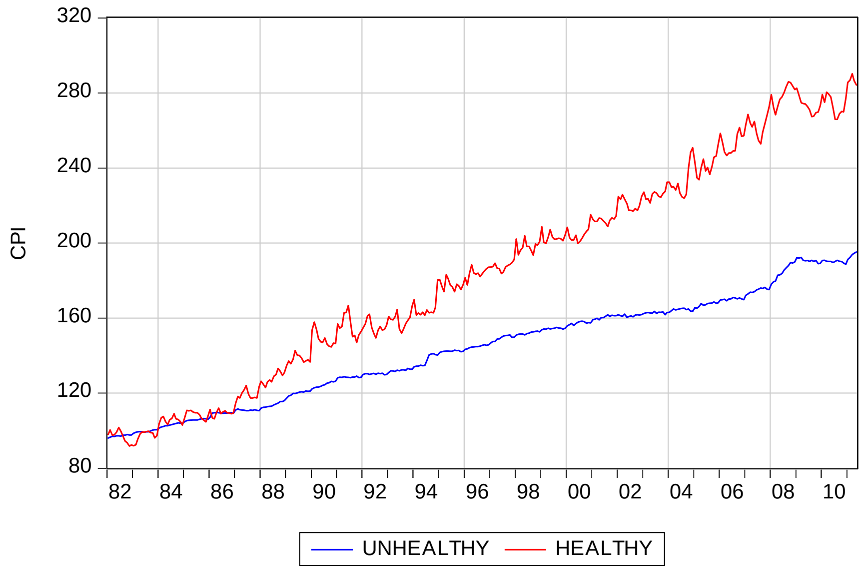

Figure 3.2: CPI of "Healthy" and "Unhealthy" Foods, 1982.01-2011.05
(Source: Bureau of Labor Statistics)

reason that fruits and vegetables have been categorized as "healthy" foods. Conversely, food items categorized as "unhealthy" are high in calories, yet they lack significant nutritional value. Several of the foods within the "unhealthy" category have been processed, packaged, or in some way modified. "Foods more dependent on technology are often those with the greatest amounts of added sugars and fats and therefore the highest in calories" (Finkelstein and Zuckerman, 2008, 23). Their comparison reveals that it has become more expensive for Americans to consume healthier foods and comparatively less expensive for them to consume unhealthier foods. For the millions of Americans living on a tight budget, "unhealthy" foods have become the cheapest immediate source of energy they can get (Finkelstein and Zuckerman, 2008, 8).

As Pollan (2006) points out, corn production has historically been a beneficiary of massive government subsidies, as U.S. policy has targeted low corn prices since 1973 (Pollan, 52). Due to corn's increasing presence in the processed food industry, there is

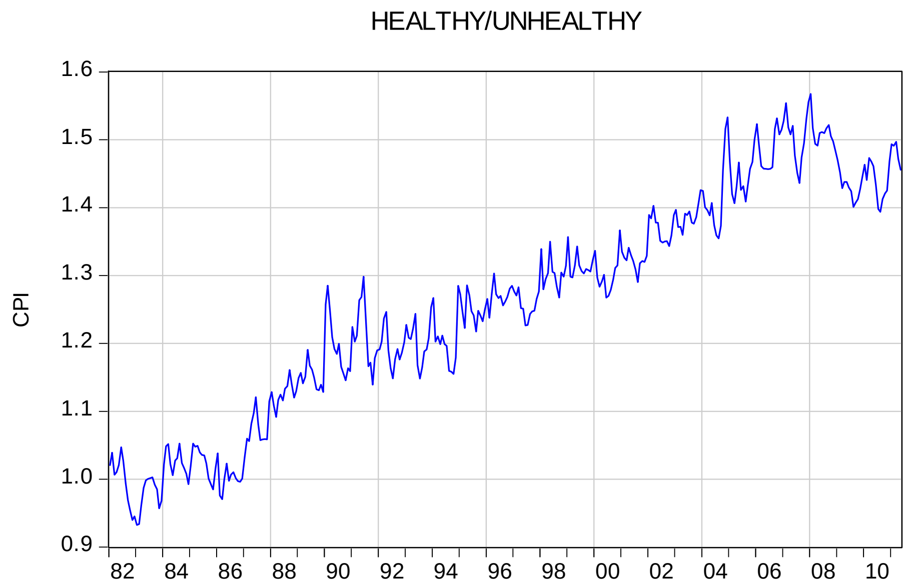

Figure 3.3: Relative Prices of "Healthy" and "Unhealthy" Foods, 1982.01-2011.05
(Source: Bureau of Labor Statistics)

reason to believe that corn plays a major role in relative food prices. It is interesting to note that in Figure 3.3 relative food prices have trended downwards since 2008, perhaps a result of the additional 3.7 billion bushels of corn devoted to ethanol from 2000-2009 (Wallander et al, 2011, 3). We hypothesize that rising corn prices have raised the price of "unhealthy" foods, thus lowering relative food prices in recent years.

Using relative food prices as the dependent variable and corn prices as the independent variable, Stage 2 will use cointegration testing to determine if a significant long-run relationship exists between the two variables. Similar to Stage 1, the Granger causality test will then be applied to determine if corn prices are in fact driving relative food prices as we hypothesized. If a cointegrating relationship exists between corn prices and relative food prices, Stage 3 of our analytical approach will model the relationship between meat prices and obesity, as well as, relative food prices and obesity.

Stage 3: Food Prices and Body Mass Index

The final phase of our analytical approach will assess the relationship between meat prices, relative food prices and the percentage of the U.S. population categorized as "obese" according to BMI reports. Since about the 1960's America has witnessed a steady rise in the number of people that are obese (See Figure 3.4). In recent years, roughly one in every three Americans can be labeled as obese. The existing literature, primarily that of Finkelstein and Zuckerman (2008), provides us with ample reason to believe that relative food prices play a major role in the current obesity epidemic. The law of demand would have us believe that the cheaper food is the more of it we consume, precisely the situation we have faced for the past four decades. "Since 1960, the relative price of food compared with other goods has decreased by about 16% percent. Since 1978, food prices have dropped 38 percent relative to the prices of other goods and services" (Finkelstein and Zuckerman, 2008, 21). However, it is not just that food in general has become cheap, it is the *types of food* that have become cheap. Compared with healthy foods such as fruits and vegetables, energy dense foods have become increasingly cheaper, as illustrated by Figure 3.2. Between 1983 and 2005, the price of fruits and vegetables has risen 190 percent, whereas foods such as fats and oils, sugars and sweets, and non-alcoholic beverages have risen by much smaller amounts–70 percent, 66 percent, and 32 percent respectively (Finkelstein and Zuckerman, 2008, 21). Such price adjustments for food have not only shifted consumption towards "unhealthy" foods, but it has increased typical portion sizes as well. A 20-oz soda has replaced the once typical 8-oz version, snacking has become a standard activity between meals, and the term "supersize me" has grown to be a common American colloquialism (Finkelstein and Zuckerman, 2008, 22). It should be noted too that even slight caloric imbalances could lead people to become obese over time. Finkelstein and Zuckerman (2008) estimate that

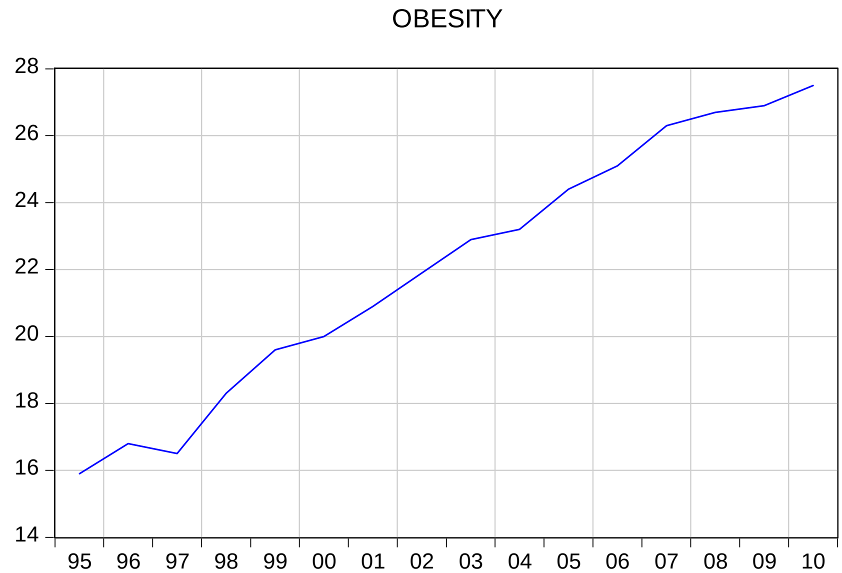

Figure 3.4: Percentage of U.S. Population that is Obese, 1995-2010
(Source: Center for Disease Control)

eating just 100 extra calories a day could generate an average gain of 10 lbs per year. This fragile maintenance of the recommended 2,500 calories-a-day diet could be swiftly violated by just 4 Hershey's Kisses, 2 Oreo cookies, 10 French fries, an 8-oz Coca-Cola, or 1 tablespoon of peanut butter (Finkelstein and Zuckerman, 2008, 19). While there are certainly numerous other factors that influence obesity (i.e. socioeconomic status, physical activity, genetic makeup, etc.), the existing literature confirms that relative food prices seem to be among the most prominent. It is for these reasons that relative prices of "more" and "less" healthy foods and BMI data will be modeled in this final phase of the model.

Stage 3 of the analytical approach attempts to provide the answer to the ultimate question of this study: Does an increase in U.S. corn ethanol production cause Americans to eat healthier? BMI data is a relatively recent attempt at quantifying obesity, and thus, its availability is limited. This stage will look at food prices and the percentage of Americans that are "obese" from 1995-2010 on an annual basis. Due to the small sample size, cointegration testing would be invaluable, so ordinary least squares regression analysis will be performed instead. In the next chapter, we will present and analyze our empirical findings.

Chapter 4

Analysis of Empirical Results

This chapter presents the findings of the econometric analysis as outlined in the previous chapter. Corresponding to the structure of our analytical approach, the results are introduced in three stages. The first section discusses the relationship between ethanol prices and corn prices. The second section discusses the relationship between corn prices and food prices, while the third section discusses the relationship between food prices and obesity.

4.1 Stage 1: Ethanol Prices vs. Corn Prices

Stage 1 of our analytical approach examines the relationship between U.S. ethanol prices and U.S. corn prices.

Unit Root Tests

As mentioned in Chapter 3, cointegration techniques pertain to testing relationships among nonstationary variables. Therefore, prior to estimating cointegration equations, each variable being used must submit to a unit root test to confirm that it is in fact nonstationary. Stage 1 uses two variables, the monthly price per gallon of ethanol and the monthly price per bushel of corn received by U.S. corn farmers.

The estimated p-value for ethanol and corn prices was 0.17 and 0.62 respectively (Appendix B, Table 2). Both values are not significant at the 5% level, and thus, we fail to reject the null hypothesis that the variable has a unit root. In other words, both ethanol and corn prices are nonstationary and are eligible for cointegration testing.

Cointegration Test

The cointegration test for Stage 1 uses corn prices as the dependent variable and ethanol prices as the independent variable. We have set up the variables in this way because the literature suggests that an increasing demand for ethanol (as represented by higher prices) is driving higher corn prices. The configuration of this regression estimates the effect that ethanol prices have on corn prices.

Just as Serra et al. (2010) report in their study, the findings of this test suggest that a long run (cointegrating) relationship exists between corn and ethanol prices. Furthermore, we may conclude that the relationship between corn and ethanol prices is positive and robust. As shown in Appendix B (Table 2), the estimated t-statistic for ethanol is 6.43. This value is much higher than the value required for significance at the 5% level, indicating that the cointegrating relationship between the two variables is very significant as is represented by the extremely low p-value (0.000). The coefficient of ethanol is 1.15, meaning that a $1 increase in the price of ethanol results in a $1.15 increase in the price of corn. This estimation supports our hypothesis that higher ethanol prices result in higher corn prices. The adjusted R-squared value is 0.33, which tells us that only 33% of the variability in corn prices is explained by the relationship with ethanol prices. Given the low adjusted R-squared value, we can assume that other factors affect corn prices other than the price of ethanol. This makes sense since there are numerous other factors that influence the price of corn (i.e. corn's demand for non-ethanol uses, government subsidies, crop yield, production costs, etc.). In any case, the fact that about one-third of corn price variability may be explained by ethanol prices alone, highlights that ethanol has a relatively substantial impact on corn prices. However, to the extent that other factors play a role in determining the price of corn, we must be cautious when interpreting results in the following stages of our analytical approach.

Granger Causality Test

The Granger causality test aims to determine the direction of influence between corn prices and ethanol prices. Multiple tests were performed in order to look at the results for various lag periods. The lag periods of two months and up to twelve months were used. Lag values are included to analyze any delayed effects that one variable may have on the other.

Contrary to our predictions, the results of the Granger causality test do not indicate that ethanol prices drive corn prices at any of the lag values observed. Conversely, the test results do in fact indicate that corn prices drive ethanol prices at each of the lag values observed. This makes sense since corn prices are the primary input of ethanol, so as corn prices rise, ethanol prices are likely to rise in response. While this may be true, Serra et al. (2010) suggest that rising ethanol demand has driven higher corn prices, particularly in the latter part of the 2000's. To accommodate for the recent expansion in the ethanol industry, Granger causality tests were performed using a sample of 2006.01-2011.05 and examined for the lag values of 2-12. Once again, corn prices were found to cause ethanol prices.

While our results do not support our predictions, it is important to note that the Granger causality test provides purely a *statistical* perspective on the direction of influence between two variables. The test lacks intuition and economic reasoning and due to the mathematical structure of the test, results such as these can sometimes occur.

However, based on our economic reasoning and the work of Serra et al. (2010), it is reasonable to assume that ethanol prices have caused corn prices in recent years.

In Stage 1 of our analytical approach, we have determined that corn and ethanol prices share a cointegrating relationship. Furthermore, we have examined and discussed the issue of causality between the two variables. The next section of this chapter will analyze the relationship among corn prices and food prices.

4.2 Stage 2: Corn Prices vs. Food Prices

Corn's relationship with meat prices and relative food prices will be examined in this section. Corn prices have previously been confirmed as nonstationary, and thus, our unit root testing begins with meat prices and relative food prices. Following this step, cointegration techniques are implemented to examine the existence of long run, equilibrium relationships.

Unit Root Tests

The Consumer Price Index for meats (beef, pork, poultry and fish) over the sample period (1982.01-2011.05) has an Augmented Dickey-Fuller test statistic of 1.24 (Appendix B, Table 1). The critical value at the 5% level of confidence is -2.87, and therefore, the price of meats is not stationary. The price of meats is eligible for cointegration testing.

Relative food prices (the price of "healthy" foods divided by the price of "unhealthy" foods) have a test statistic of -1.27 (Appendix B, Table 1). This value is not significant at the 5% level and we conclude that relative food prices are also a nonstationary variable. Therefore, all relevant variables have passed the unit root test and are eligible for cointegration testing.

Regression Testing

In the previous section, a cointegrating relationship between ethanol prices and corn prices was established. In an attempt to link the energy market (in particular ethanol) to the food industry, a series of regression analyses are performed. The first set of tests will model corn's relationship with meat prices and ethanol's direct relationship with meat prices. The second set of tests will model corn's relationship with relative food prices.

Michael Pollan (2006) reports that about 60 percent of America's corn crop goes to feeding livestock (Pollan, 66). Given corn's integral role in feeding America's livestock, a statistical analysis of their relationship is worthwhile. Figure 4.1 provides a visualization of corn and meat prices over the past three decades. Corn prices are in dollars per bushel and meat prices are represented by the Consumer Price Index.

Using corn prices as the independent variable and meat prices as the dependent variable, our cointegration test examines the effect that corn prices have on meat prices. The results of this test (Appendix B, Table 2) reveal that the test-statistic of corn is significant, and thus, corn prices and meat prices exhibit a long run (cointegrating) relationship. The coefficient of corn is 20.25. Since meat prices are determined by the Consumer Price Index, this coefficient can further by interpreted as follows: a $1 increase in the price of corn will raise the cost of meat products (beef, pork, poultry and fish) by roughly 20 points. To place this point increase in context, we will compare it to the historical average of the CPI for meats.

Referring to Appendix A (Table 1), we see that the mean CPI for meats over the sample period is 147.78. If we calculate a 20 point increase as a percentage of this value, we receive 0.135, indicating that, on average, a point 20 point increase in meats is roughly a 13.5% price increase. Thus, our regression estimation reveals that a $1 increase in the price of corn will raise the cost of meats roughly 13.5%.

The adjusted R-squared value for the estimated regression was low (0.22), indicating that other factors influence meat prices besides corn prices. The coefficient of correlation for the two variables is 0.47 over the entire sample period.

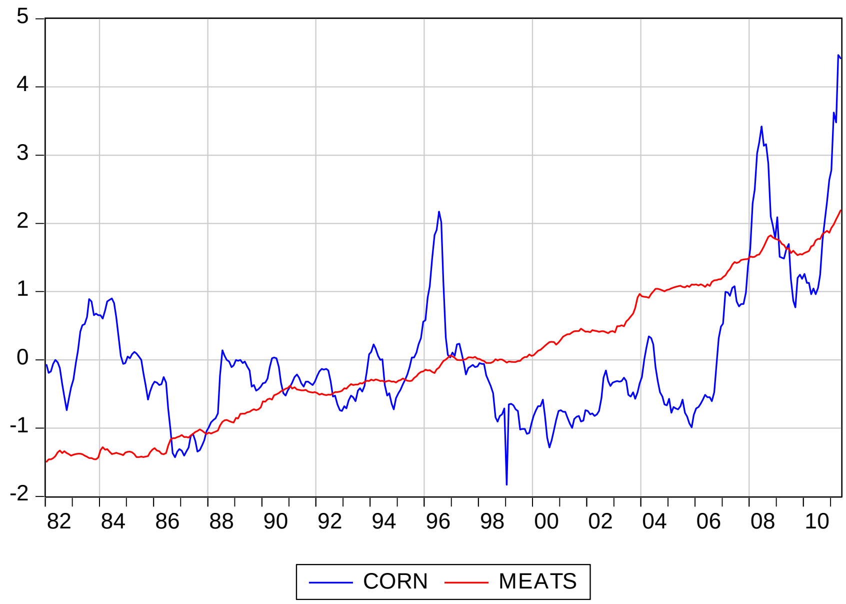

Figure 4.1: Monthly Corn and Meat Prices, 1982.01-2011.05
(Source: U.S. Department of Agriculture and Bureau of Labor Statistics)
(Note: The vertical axis represents the original data of $/ bushel and CPI. The data have been normalized for easy comparison.)[1]

As is evident in Figure 4.1, corn prices have risen tremendously since about 2006. Over the entire sample period (1982.01-2011.05), corn has exhibited an average annual price increase of nearly 3.25% (Appendix A, Figure 1). Since 2006, corn prices have

[1] Normalized data are standardized to have mean 0 and variance 1. Normalizing data allows us to interpret data variables relative the universe in which they exist.

risen by an average of nearly 25% each year (Appendix A, Figure 2). If we model the relationship between corn and meat prices since that time (Figure 4.2), the correlation coefficient increases to 0.84, and the t-statistic for cointegration testing rises from 4.36 to 7.33 (Appendix B). Furthermore, the adjusted R-squared value has improved to 0.70. The combination of these figures suggests that corn's relationship to meat has become more significant in recent years. While this may perhaps be due to cyclical adjustments, it is also a possible response to the simultaneous boom in the ethanol industry. If the latter is true, the evidence suggests that ethanol's linkage to the food industry has strengthened in recent years.

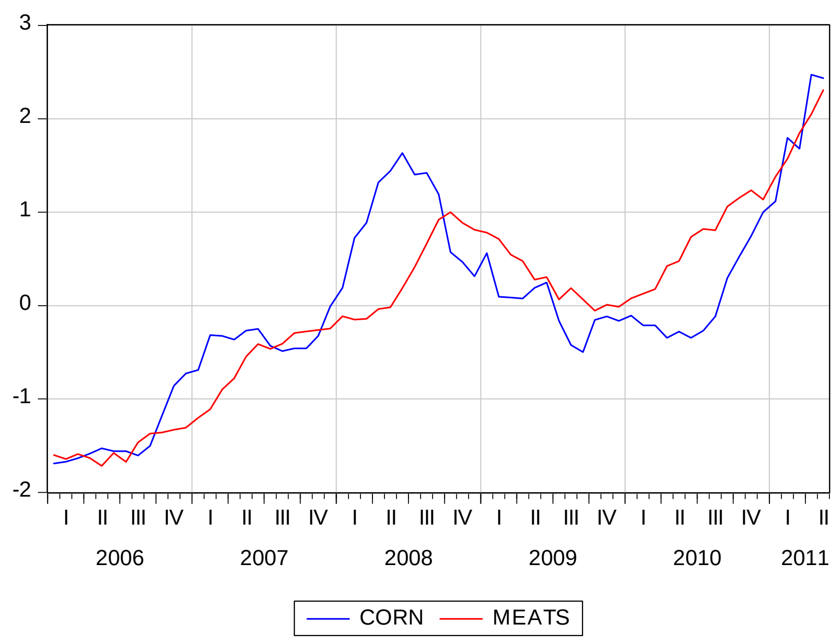

Figure 4.2: Monthly Corn and Meat Prices, 2006.01-2011.05
(Source: U.S. Department of Agriculture and Bureau of Labor Statistics)
(Note: The data have been normalized for easy comparison)

In the last six and a half years of the sample period (2006.01-2011.05), corn prices have gone from \$2.00 per bushel to \$6.32 per bushel, nearly a 220% increase. Over this period, the actual CPI for meats has risen from 185.8 to 223.2, nearly a 20%

increase. That is, in response to higher corn prices (presumably from a rise in ethanol demand) the typical basket of meat products consumed by the average American has become 20% more expensive. This relationship of the magnitude between corn prices increase and meat price increases are consistent with that of the existing literature.

Randy Schnepf (2009) reports, “Since 1950, the U.S. marketing bill has increasingly taken a larger share of the consumer food dollar, growing from 59.1% of consumer food spending to 81.5% in 2006” (Schnepf, 2009, 9). The marketing bill represents the disparity between a products farm value and its retail food price (Schnepf, 2009, 9). This disparity is constituted by inputs such as labor, energy, profits, transportation and so forth (Schnepf, 2009, 10). As the marketing bill continues to grow, food inputs such as corn have a decreasing impact on retail food prices. Leibtag (2008) writes, “While higher corn prices increase animal feed and ingredient costs for farmers and food manufacturers, it passes through to retail prices at a rate less than 10 percent of the corn price change” (Leibtag, 2008, 1). Since 2006, meat prices have increased just 20% compared to a 220% increase in corn prices. Thus, we calculate that retail meat prices have risen just 9% relative to the increase in corn prices. This result confirms the estimation of Leibtag (2008).

Schroeder et al. (2000) estimate that the own price elasticity for beef, pork and poultry are -0.61, -0.50, and -0.05 respectively. If we use the 28% increase in the CPI for meats as a proxy, the elasticities calculated by Schroeder et al. (2000) suggest that we would observe a decrease in meat consumption as follows: beef (-17%), pork (-14%) and poultry (-1.4%). Although this is an imperfect calculation, it provides us with some insight as to the relative magnitude that the consumption of various meats is affected.

Our previous calculation estimates that beef consumption is more sensitive to higher meat prices than is chicken consumption. A plausible cause for this reaction relates to the amount of corn required to feed each animal.

> "Compared to other food animals, cattle are terribly inefficient: The ratio of feed to flesh in chicken, the most efficient animal by this measure, is two pounds of corn to one of meat, which is why chicken costs less than beef" (Pollan, 80).

We have confirmed that corn and meat prices share a positive cointegrating relationship, whereby higher corn prices are accompanied by higher meat prices. Since the feed ratio for beef is the highest of any food animal, it would then make sense that a rise in corn prices affects beef prices more than other types of meat. To this degree, the fact that beef consumption is expected to have decreased the most in recent years is a reasonable assumption. Red meat, although rich in protein and B-Vitamins, has high levels of fat and cholesterol. When consumed in excess, red meat has to potential to contribute to health disorders (i.e. obesity). In the next section, we will take a closer look at this relationship. Having concluded our discussion of corn's relationship to meat prices, we will now look at corn prices and its relationship to relative food prices.

The work of both Zuckerman and Finkelstein (2008) and Pollan (2006) provide us with ample reason to believe that corn has played an integral role in maintaining cheap, high-calorie food.

The historically low price of corn can be traced back to the 1970's, in which President Nixon's second secretary of agriculture, Earl "Rusty" Butz, shifted America's food chain onto a foundation of cheap corn (Pollan, 2006, 51). With the 1973 Farm Bill, Butz abolished the farm programs apart of Roosevelt's New Deal System, and instituted a system that targeted corn prices called the "loan rate". For any gaps between the market price and the "loan rate", the U.S. government offered direct payments to farmers that covered any losses (Pollan, 2006, 49). The nature of this subsidy program would provide an incentive to farmers to grow corn over other crops, thus flooding the market and depressing corn prices. As a result, corn stands as the most subsidized crop in the U.S., receiving more than $70 billion in government subsidies between 1995 and 2010 (Carr, 2010, 1).

Provided America's abundance of cheap corn, modern food science has continually found ways to incorporate corn into food products. Corn derivatives such as cornstarch, corn syrup, and high-fructose corn syrup are abundant in foods that we have categorized as "unhealthy," as "food manufacturers have an incentive to add inexpensive corn-based products to their foods" (Finkelstein and Zuckerman, 2008, 25). To this extent, government subsidies have held the price of "unhealthy" foods relatively low. Conversely, "healthy" foods such as fruits and vegetables are subject to free market forces and have become increasingly expensive relative to "unhealthy" foods over the past three decades. Government intervention has historically held the price of corn artificially low, which is reflected by the small price increases of "unhealthy" foods in past years.

Given corn's presence in the industrial food market, our next test will model the relationship between corn prices and relative food prices. A visual representation of the price patterns for corn and relative foods can be seen in Figure 4.3.

Our cointegration test models corn prices against relative food prices and reveals that a cointegrating relationship exists among the two variables (Appendix B, Table 2).

The slope coefficient of corn is 0.07, which estimates that a $1 increase in the price of a bushel of corn will increase relative food prices (as measured by CPI) by 0.07 points. Since relative food prices are calculated by the equation

Relative Food Prices = (“Healthy” Foods) / (“Unhealthy” Foods)

the positive direction of this coefficient suggests that an increase in corn prices either relatively raises the price of “healthy” foods or makes “unhealthy” foods relatively cheaper, both of which are contrary to our assumptions due to corn’s larger presence in “unhealthy” foods. The adjusted R-squared value is 0.12, indicating that only 12% of the variation in relative food prices can be explained by its relationship with corn prices. The nature of this value provides strong reason to believe that other factors play a role in determining relative food prices (i.e. marketing costs, input prices, etc.). Furthermore, the Durbin-Watson statistic is an extremely low 0.03, indicating the presence of serial auto-correlation. The strength of these results is weak, and additional analysis will be performed in correspondence to particular trends in Figure 4.3.

Figure 4.3 highlights some interesting trends between corn prices and relative food prices. While our cointegration test reveals that a long run equilibrium relationship exists between the two variables, a fair degree of variation is present between their trends. As is visually evident, the linkage between corn and relative food prices remained reasonably stable from the beginning of the sample until roughly the end of 1997. Following this period, corn prices dropped substantially and disrupted the existing pattern. The cause of this trend can be attributed to two successive occurrences. First, the

1996 price grain shock took place in response to the Midwestern drought, rising export demand, and commodity market speculations (Light and Shevlin, 1998, 1). This price shock is evident in Figure 4.3 as corn prices sharply increased in 1995-96. Second, the Federal Agriculture Improvement and Reform Act of 1996, commonly called the Freedom to Farm Act, eliminated farm program provisions that moderated crop prices in the past (Policy Matters, 1). Consequently, the price floor was removed and corn prices plummeted from their high levels during the price shock earlier that year. Since that time, corn prices exhibited little growth until the mid 2000's. Due to the disturbance in corn prices caused by the Freedom to Farm Act, further analysis is performed to strengthen our previous results regarding corn's relationship with relative food prices.

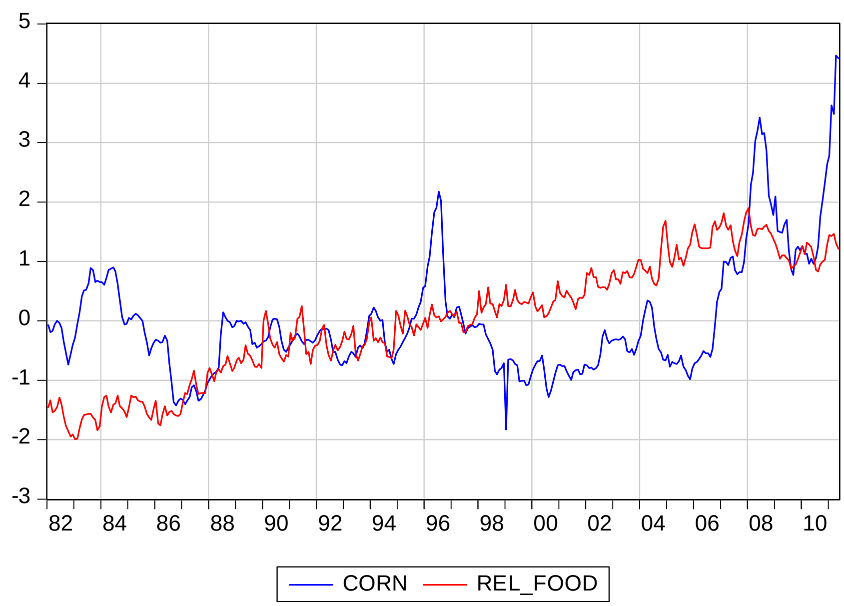

Figure 4.3: Monthly Corn and Relative Food Prices, 1982.01-2011.05
(Source: U.S. Department of Agriculture and Bureau of Labor Statistics)
(Note: The data have been normalized for easy comparison)

In an attempt to capture the disruption in corn's relationship to relative food prices, the sample period has been broken into two periods, 1982.01-1997.12 and 1998.01-2011.05. The two sample periods have been chosen according to noticeable trends in Figure 4.3 that correspond with the farm policy reform in the 1990's. Utilizing OLS regression analysis, both an intercept dummy variable and a slope dummy variable are implemented to adjust for the influence of the Freedom to Farm Act. The period of 1982.01-1997.12 is assigned a dummy variable equal to 0 (meaning no exogenous factor has influenced the relationship) whereas the period of 1998.01-2011.05 is assigned a dummy variable equal to 1 (meaning some exogenous event has taken place, thus influencing the relationship). The introduction of the two dummy variables will adjust our regression for changes in both the intercept and the slope in the latter period. Furthermore, because of the indication from the Durbin Watson statistic that positive autocorrelation exists, we use Cochrane-Orcutt procedure. Having implemented the aforementioned variables, we then re-estimate our original model with the following equation:

$$y = \beta_0 + \beta_1 x + \beta_2 dum + \beta_3 dum*x + ar(1) \qquad \textbf{(1)}$$

where y is relative food prices, β_0 is the intercept, x is corn prices, *dum* is the intercept dummy, *dum*x* is the slope dummy and *ar(1)* specifies our first order autoregressive component. Our results produce the following two estimations (Appendix B, Table 4):

1982.01-1997.12: $y = 1.22 + 0.02x$

1998.01-2011.05: $y = 1.22 + 0.02x + 0.14 – 0.03x$
$y = 1.36 – 0.01x$

These equations indicate that prior to 1998, a \$1 increase in the price of corn raised relative food prices by 0.02 points. The positive direction of this relationship is the same as we observed in our cointegration estimation and contradicts our hypothesis. However, the second equation indicates that since 1998, a \$1 increase in corn prices decreased relative food prices by 0.01 points. This estimation of the latter period corroborates or original hypothesis that an increase in the price of corn makes “unhealthy” foods more expensive, thus decreasing relative food prices. In summary, the empirical results suggest that post-1998, rising corn prices have made “healthy” foods relatively cheaper (or “unhealthy” foods relatively more expensive).

The significance of these estimations is substantially stronger than that of our previous results (Appendix B, Table 4). Corn prices and the slope dummy are significant at the 10% level, whereas the intercept dummy and the autoregressive term are significant at the 1% level. Our Durbin-Watson statistic has improved to 1.82. Using Durbin-Watson tables, this value indicates that our new estimation lacks autocorrelation given its number of regressors and sample size. Moreover, our adjusted R-squared value has dramatically improved to 0.98, indicating that after we have adjusted for changes in the posited relationship, 98% of the variation in relative food prices can be explained by changes in corn prices. The nature of these findings is robust and we may interpret the relationship between corn prices and relative food prices with confidence.

It is interesting to note that the change in the orientation in the relationship corresponds to acceleration in ethanol production in the late 1990’s and encompasses the ethanol boom in the mid-2000’s. Having confirmed that ethanol and corn prices share a cointegrating relationship (although possessing a low adjusted R-squared value), this recent trend is likely to be caused by an increase in ethanol production. Therefore, to the extent that ethanol production influences corn prices, and thus relative food prices, it is reasonable to presume that a booming ethanol industry has triggered a decline in the relative price of "healthy" and "unhealthy" foods. The effect that food prices have on America's obesity epidemic will be examined more closely in the following section.

Having concluded our discussion of corn's relationship with relative food prices, we will now implement the Granger causality test to determine the direction of influence between corn prices and meat prices, as well as, corn prices and relative food prices.

Granger Causality Test

Two series of Granger causality tests will be performed. The first set of tests will look at corn prices and meat prices, whereas the second test will look at corn prices and relative food prices.

The first set of tests reveal some interesting results. Meat prices were shown to cause corn prices for lag values of 4-6 months. This potentially results from a fluctuating demand in the livestock industry that requires a proportional amount of corn. On the other hand, the results indicate that corn prices cause meat prices for the lag values of 6-20 months. This is an interesting finding since it takes a long time for animals (some longer than others) to mature and reach an appropriate size for slaughter. Since meat prices are determined once an animal is delivered onto the market, it makes sense that a longer delay exists between corn prices causing meat prices. In summary, meat prices cause corn prices in the short run, whereas corn prices cause meat prices in the long run.

The results of the second set of tests reveal that relative food prices cause corn prices at a lag of 2 months. This is possibly due to the demand for corn in the food industry. Corn prices were not determined to drive relative food prices at any of the observed lags.

Having discussed our findings for corn's relationship to meat prices and relative food prices, as well as the issue of causality between the relevant variables, the next section will look at the relationship that meat prices and relative food prices have on obesity.

4.3 Stage 3: Food Prices vs. Obesity

This section will focus on the relationship among food prices and obesity statistics. Unlike the previous two stages of the model, this stage uses annual figures due to limitations regarding BMI data. Given the restricted number of observations, OLS regression analysis is utilized instead of cointegration testing. This section presents the results on the final stage of our model approach. Its goal will be to tie together the results of the previous two sections and answer the thesis question at hand: Does an increase in U.S. corn-ethanol production have a beneficial impact on America's obesity epidemic?

Relative Food Prices and Obesity

In the previous section of this chapter, we confirmed that a cointegrating relationship exists between corn prices and relative food prices. Furthermore, in an additional analysis we determined that rising corn prices since 2006 have caused relative food prices to decline. Having established this relationship, we will now turn to the relationship between relative food prices and obesity.

Finkelstein and Zuckerman (2008) note that there is an inverse relationship between soda consumption and soda prices relative to overall food prices (Finkelstein and Zuckerman, 21). Inspired by this finding, we then applied this concept to our study of relative food prices and obesity. We hypothesized that, to the extent that people respond to relative food prices, we would see a shift in consumption away from "unhealthy" foods and towards "healthy" foods. This shift would in turn slow down the rising population of obese Americans. As our regression reveals, relative food prices have a tremendous impact on the number of obese people in America.

The coefficient of relative food prices has a t-statistic of 10.93, indicating high significance between the two variables (Appendix B, Table 5). The coefficient of relative food prices is 41.67. Since the obesity is measured as a percentage of the American population, the coefficient of relative food prices suggests that a 1 point increase in the index relative food will cause the percentage of obese Americans to increase by 41.67% in a year. The regression of obesity on relative food prices has an adjusted R-squared value of 0.89, meaning that 89% of the variation in obesity can be explained by its relationship with relative food prices. This adjusted R-squared value is high and suggests that relative food prices are largely responsible for the variation in obesity. However, the Durbin-Watson statistic is 0.71, indicating that positive serial correlation exists. The presence of serial correlation has likely overestimated the coefficient of relative food. To correct for this, we use Cochrane-Orcutt procedure. Thus, our new regression estimation equation is as follows:

$$y = \beta_0 + \beta_1 x + ar(1) \quad \textbf{(2)}$$

where y is the percentage of obese Americans, β_0 is the intercept, x is relative food prices and $ar(1)$ specifies our first order autoregressive component.

Using Cochrane-Orcutt procedure improves our results (Appendix B, Table 5). The Durbin-Watson statistic is now 2.87. Although this value signifies negative serial correlation now exists, it is closer to the ideal value of 2, thus improving from our last test. The adjusted R-squared value has increased to 0.99, indicating that 99% of the variability in obesity is attributed to relative food prices. The adjusted R-squared value reveals that obesity is highly dependent on relative food prices. The coefficient of relative food has decreased (as we expected) to 9.78 and remains significant at the 5% level. This value indicates that a 1 point increase in the index of relative foods will increase America's percentage of obese people by 9.78%. Based on the value of this coefficient and the U.S.'s current population of roughly 313 million (Schlesinger, 2011), this estimation insinuates that a 1 point increase in the index of relative food prices would create an additional 30.6 million obese Americans. The magnitude of this statistic is astounding and highlights the fact that even small discrepancies food prices can have a major impact on the diet choices of consumers. As discouraging as this finding may be, Figure 4.4 illustrates some promising trends.

Over the entire sample period, the correlation coefficient of relative food prices and obesity is 0.95 (Appendix B, Table 8), indicating that relative food prices and obesity have been highly correlated since 1995. More importantly, this strong correlation reveals that as "unhealthy" foods become increasingly cheap relative to "healthy" foods, a rising number of people acquire unhealthy diet patterns. That is, to the extent that consumers respond to financial incentives, an increase in relative food prices over the years has created higher rates of obesity. However, as is evident in Figure 4.4, since mid-2006

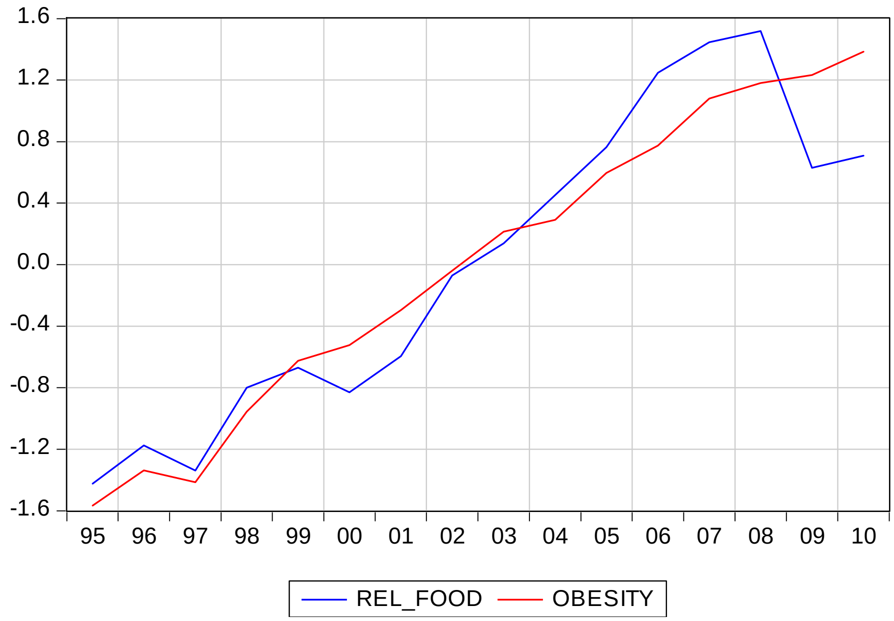

Figure 4.4: Relative Food Prices and the Percentage of Obese Americans, 1995-2010
(Source: Bureau of Labor Statistics and Center of Disease Control)
(Note: The data have been normalized for easy comparison)

relative food prices began exhibiting diminished growth, and in late 2009 relative food prices actually dropped rather substantially. Coinciding with this trend, in late 2007 there appears to be a kink in the obesity graph that signals a slower growth of obesity than in previous years. Concurrent with the timing of these trends is the onset of America's current recession.

Researchers have linked unemployment to obesity, and since the recent economic meltdown in 2008, the unemployment rate has spiked from 6% to 9.7% (Casserly, 2010, 1). Casserly (2010) reports three key reasons for weight gain during recessions, "loss of self-esteem, a more sedentary lifestyle and less money to spend on food and gym membership" (Casserly, 2010, 1). Less money to spend on food is likely to translate to more consumption of "unhealthy" foods. Finkelstein and Zuckerman (2008) calculate that "it will cost you roughly 80 cents to eat 1,000 calories of potato chips. In comparison, to eat 1,000 calories worth of fresh carrots, you would have to plunk down about $4" (27). Although research suggests that higher unemployment contributes to increased obesity rates, we have witnessed a slowing of America's obesity epidemic since that time. The nature of this phenomenon suggests that declining relative food prices have overpowered the unemployment effect.

The existence of the two aforementioned trends suggests that lower relative food prices (resulting from higher corn prices and rising ethanol demand) have shifted consumption in a healthier direction. Despite the opposing forces of unemployment, declining relative food prices appear to be slowing down America's obesity epidemic. Given that this is a recently observed phenomenon consisting of only a few observations, we are not able to make any firm conclusions based on the past few years nor are we able to extrapolate this trend into years beyond the sample period. Nevertheless, it does appear that obesity trends are heading in an encouraging direction.

The relationship between relative food prices and obesity appears to be going in a direction that corresponds to a healthier America. We will now examine obesity's relationship with other food items to see if they too support our argument that increased ethanol production slows down America's obesity epidemic.

Meat Prices and Obesity

Earlier this chapter we established that meat has a cointegrating relationship with corn prices. Several types of meat have the potential to be unhealthy when consumed in irresponsible amounts. To this extent, the relationship between meat prices and obesity is useful to analyze. Figure 4.5 shows meat prices and the percentage of America's population that is obese.

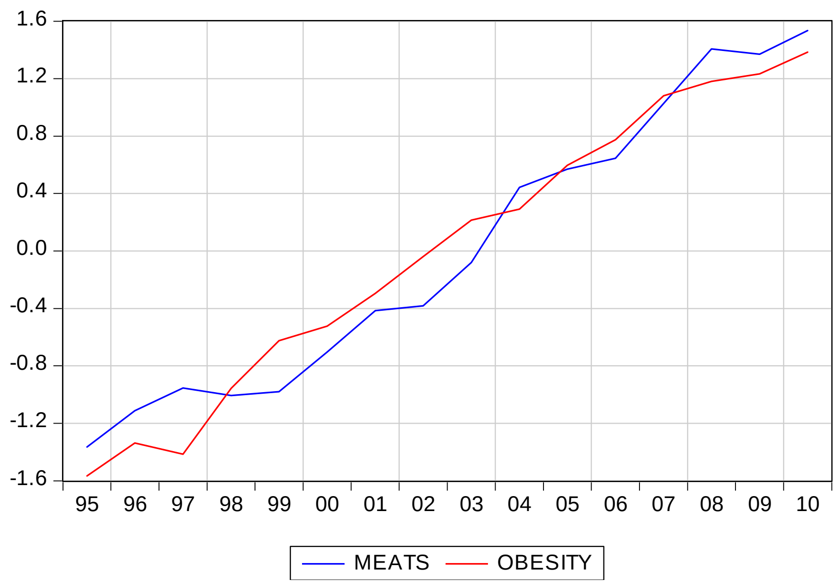

Figure 4.5: Meat Prices and the Percentage of Obese Americans, 1995-2010
(Source: Bureau of Labor Statistics and Center for Disease Control)
(Note: The data have been normalized for easy reading)

The regression results of meat prices and obesity (Appendix B, Table 5) does not provide us with any substantial insight. While the regression estimations suggest an extremely strong relationship exists between the two variables (t-statistic = 75.6), their relationship is positive and suggests that an increase in meat prices leads to higher obesity rates. To the extent that people respond to incentives, this figure may insinuate that an increase in meat prices may lead people to consume cheaper, yet unhealthier alternatives to meat. Furthermore, we also modeled meat prices relative to overall food prices with obesity and the results remain inconclusive. The connection between meat prices and obesity offers little significance to the nature of this study, and we will now shift focus to Big Mac prices and obesity.

Big Mac Prices and Obesity

Khan et al. (2011) report that an increase in fast food prices is associated with less fast food consumption among American children. To this extent, we have modeled the price of McDonald's signature item, the Big Mac, and obesity (Figure 4.6).

Figure 4.6 presents subtle evidence that higher Big Mac Prices may play a part in the slowing of the obesity rate in recent years. If we look at the year 2006, Big Mac prices began a period of considerable growth, then in 2007, the rate at which obesity rises seems to detract from that of previous years. While this observation alone does not provide substantial grounds to deduce conclusions regarding the two variables, it is interesting to note that this trend transpires in concurrence with that of relative food prices and obesity. Big Mac prices relative to overall food prices were also modeled with obesity; no new results appeared.

As Pollan (2006) discusses extensively, the modern fast food meal is heavily dependent on corn-derived products. In fact, upon submission to a food lab, Pollan (2006) presents some staggering figures on corn's presence in everyday fast food items. He writes:

> "In order of diminishing corniness, this is how the laboratory measured our meal: soda (100-percent corn), milk shake (78 percent), salad dressing (65 percent), chicken nuggets (56 percent), cheeseburger (52 percent), and French fries (23 percent)" (Pollan, 117).

Given corn's extensive use in fast food, it is worthwhile to examine the relationship of Big Mac prices with corn prices. Moreover, given ethanol's recent production boom and its impact on corn prices, both corn prices and ethanol prices are modeled with Big Mac prices (Figure 4.7).

The correlation coefficient of Big Mac prices with corn and ethanol is 0.67 and 0.82 respectively (Appendix B). Interestingly, the correlation of Big Mac prices with ethanol prices is actually higher than that of Big Mac prices and corn prices. This is surprising since corn not ethanol, is an input in Big Macs. As we have previously mentioned in our discussion of the

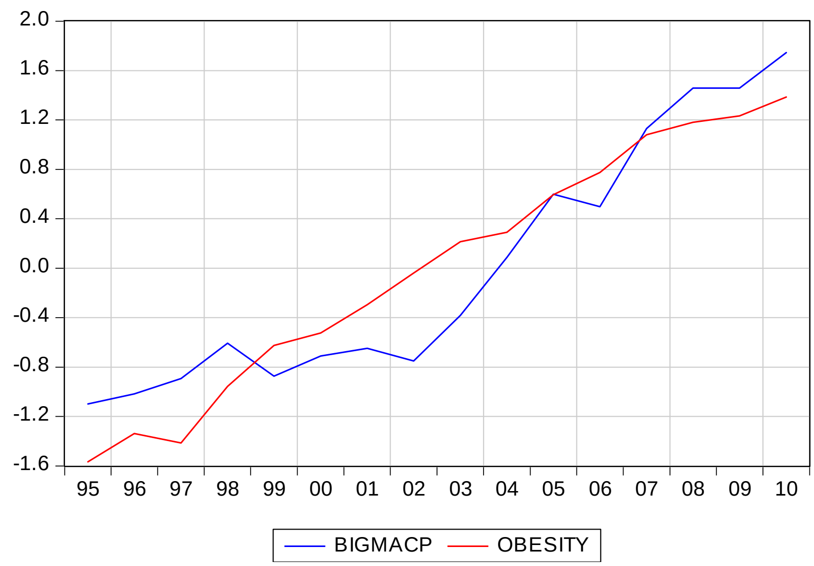

Figure 4.6: Big Mac Prices and the Percentage of Obese Americans, 1995-2010
(Source: *The Economist's*: Big Mac Index and Center for Disease Control)
(Note: The data have been normalized for easy comparison)

Granger causality test, this could simply be due to statistical coincidence. Although, given the nature of potential lags that exist, plus various interactions among sectors, it is possible that the relationship between energy and food markets has indeed tightened. To confirm this proposition, further research is needed that goes beyond the scope of this study. Nevertheless, given the nature of this finding, we will now take a more in-depth look at ethanol's direct relationship to obesity.

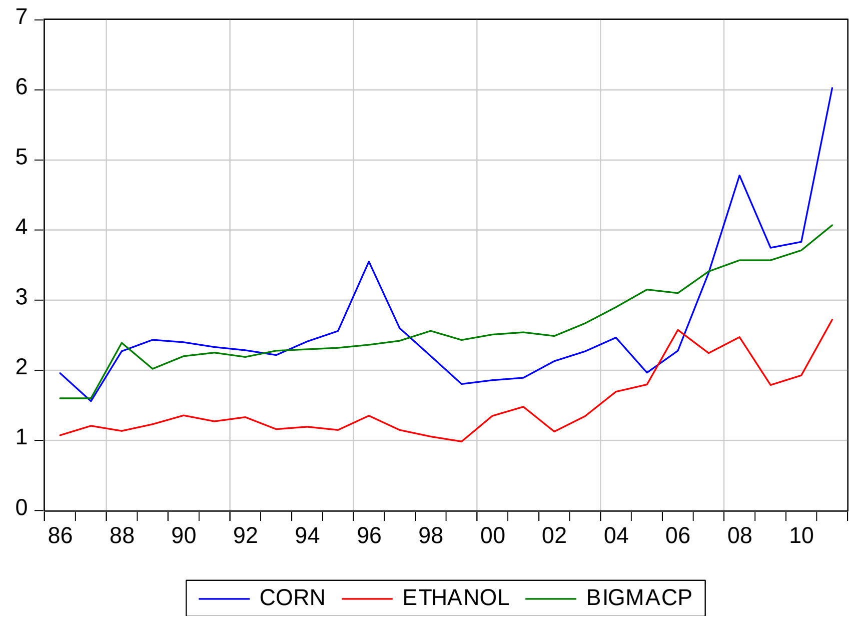

Figure 4.7: Corn, Ethanol, and Big Mac Prices, 1995-2010
(Source: U.S. Department of Agriculture and *The Economist's*: Big Mac Index

Ethanol Prices and Obesity

The OLS estimation for ethanol prices and obesity (Appendix B, Table 5) shows that a positive and significant relationship exists between the two variables. The adjusted R-squared value is 0.61, indicating that 61% of the variation in obesity is dependent on ethanol prices. The positive orientation of this relationship tells the following story based on our previous discussion: an increase in ethanol prices causes higher corn prices; higher corn prices lower relative food prices; lower relative food prices increases obesity. The last segment of this sentence insinuates that lower relative food prices drive higher obesity rates, whereas we have previously shown the opposite effect to occur. While a positive relationship may exist for the entire sample period, if we take a closer look at our sample some interesting trends appear.

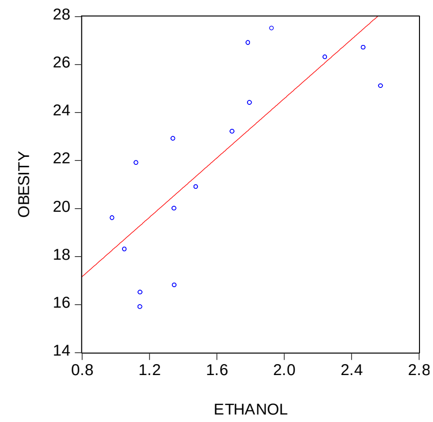

Figure 4.8: Scatter Plot of Ethanol Prices and Obesity, 1995-2010
(Source: U.S. Department of Agriculture and Center for Disease Control)

Figure 4.8 shows a scatter plot for ethanol and obesity data for the entire sample period (1995-2010). The residual line within the graph clearly demonstrates that a positive relationship exists from 1995-2010. However, if we look at just the last 5 years of the sample (2006-2010), the relationship between ethanol and obesity is negative (See Figure 4.9).

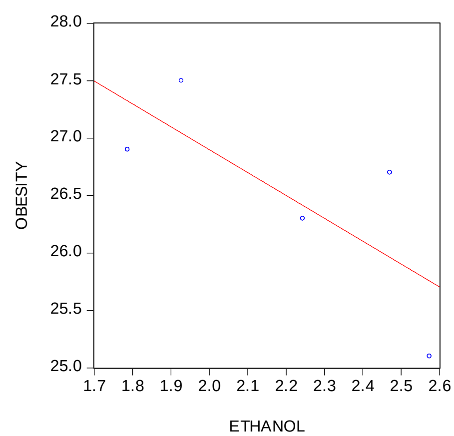

Figure 4.9: Scatter Plot of Ethanol Prices and Obesity, 2006-2010
(Source: U.S. Department of Agriculture and Center for Disease Control)

This finding suggests that in the latter part of the decade, as ethanol production surged, an increase in ethanol prices led to a decline in obesity. While these results support our hypothesis that an increase in ethanol production would slow down America's obesity epidemic, the negative relationship we have observed uses annual data and contains only five observation points. Given this limited sample size, we cannot make any firm statements regarding ethanol's *direct* relationship to obesity. However, with the accumulation of data over time, this relationship lends itself to a more accurate analysis in the future.

Chapter 5

Conclusion

5.1 Summary of Results

In Stage 1 of our analytical approach, we confirm that ethanol prices and corn prices exhibit a long run (cointegrating) relationship. This finding corroborates the work of Serra et al. (2010), whose model reveals that a strong link between corn and energy markets exists (Serra et al, 44). Moreover, the link between corn and energy markets occurs primarily through the ethanol market (Serra et al., 44). Our Granger Causality test revealed that ethanol does not cause prices as we hypothesized. However, the work of Serra et al. (2010) supports our hypothesis, stating, "Large price increases in the second half of the 2000's were, at least partially, due to the expansion of the ethanol industry" (42). Given our economic reasoning, as well as the findings of Serra et al. (2010), we are still reasonably certain that the ethanol boom in the latter half of the 2000's caused higher corn prices.

Stage 2 of our analytical approach examined the effect that corn prices has on food prices, in particular the price of meat products and the relative price of "unhealthy" and "unhealthy" foods. Corn prices proved to have significant long run relationships with both meat prices and relative food prices. The nature of these findings are consistent with the existing literature, particularly that of Zuckerman and Finkelstein (2008) and Pollan (2006), who extensively discuss corn's integral role in the American food market. Corn's relationship with meat prices has strengthened since 2006, as meat prices have closely tracked rising corn prices. Moreover, higher corn prices in recent years have lowered relative food prices, making "healthy" foods relatively cheaper.

The third and final stage of our analytical approach analyzes the effect that various food prices have on America's population of obese people. Our strongest results reveal that a very tight relationship exists between relative food prices and obesity. Interestingly, as corn prices have increased (presumably as a result of the ethanol boom), relative food prices have declined, which in turn has appeared to slow the rate of America's growing population of obese people. The prices of meat products and of McDonald's "Big Mac" were shown to have an inconclusive effect on obesity. Lastly, we examined ethanol's direct relationship to obesity, despite the different markets that ethanol must go through to actually affect consumer diet choices. To our surprise, ethanol exhibited a significant relationship with obesity, and more importantly, an increase in ethanol prices led to a decrease in obesity since 2006.

The nature of our empirical results suggests that an increase in U.S. ethanol production (by affecting the food market) has decelerated America's obesity epidemic. While these findings support our original hypothesis, the trends pointing to a healthier America have transpired in just the past few years. Whether these trends are a short-term fluctuation that will be smoothed over time, or whether ethanol production will have a lasting and profound impact on obesity can only be determined with the course of time. Nevertheless, certain occurrences may help us in predicting where these trends are heading.

5.2 Sources of Error

While our findings support the hypothesis set forth at the beginning of this study, there are some issues of validity that must be addressed.

As we have previously noted in Chapter 4, statistical errors are carried throughout the stages of our analytical approach. These errors occur primarily in the form of weak adjusted R-squared values, much as we saw in Stage 1 with our regression of ethanol prices and corn prices. The adjusted R-squared value in Stage 1 was 0.33, indicating that other factors influence corn prices besides ethanol demand. To the extent that this is true, the assumptions made onward in our analytical approach are not entirely accurate. Weak adjusted R-squared values appeared a few times throughout our analytical approach, which has the potential to lessen the strength of our results in Stage 3. Be that as it may, a direct analysis was performed between ethanol prices and obesity in Stage 3. The results indicate that a *direct* relationship exists between ethanol and obesity, which suggests that the statistical errors produced from weak R-squared values, may not have had a profound impact on our ultimate results.

The problem of serial correlation arose during our analytical approach. To correct for this, Cochrane-Orcutt procedure was used. While the implementation of this procedure improved our Durbin-Watson statistic in all cases, the first observation is lost due to the structure of the procedure. In Stage 3, Cochrane-Orcutt procedure was used for the regression analysis of relative food prices and obesity. This analysis used just 16 observations; thus, Cohrane-Orcutt procedure reduced an already small sample size. The small sample of this test is likely to contribute to reduced validity. In addition, it is important to note that Cochrane-Orcutt procedure did not eliminate the serial correlation of this regression, it merely improved it. This too has likely reduced the validity of this regression.

Stage 3 of our analytical approach uses annual data for a sample containing just 16 observations. The size of this sample is less than ideal, and serves as another source of error in our statistical analysis. Furthermore, any of the regressions that were performed using OLS are susceptible to spurious regression results, which have been previously mentioned in Chapter 3.

5.3 Policy Implications

Government policies are very influential to the findings of this study. Should agricultural policy be reformed, major changes are likely to occur in the market for corn, much as we saw in 1996 with the Freedom to Farm Act. The cost of growing corn has been above its market price since the 1970's, and government subsidies are the only reason American corn farmers remain in business (Pollan, 53). Should the government choose to lessen corn subsidies or even remove subsidies altogether, corn is likely to experience an unprecedented price shock. However, given the profound impact that higher corn prices are likely to have on food price inflation, it is unlikely that the U.S. government will make any such reforms in the foreseeable future.

The findings of this study suggest that the ethanol boom in the mid-2000's has affected relative food prices in a way such that people have shifted their consumption from "unhealthy" foods and towards "healthy" foods. Thus, to the extent that relative food prices affect obesity rates, the results of this study suggest that ethanol production is the root cause of America's slowing obesity trend. However, ethanol production appears to have reached its ceiling. The surge in ethanol production over the past decade has been the result of ethanol's replacement of MTBE and the 10% ethanol-gasoline mandate. As ethanol appears to be reaching its "blend wall," production rates are likely to remain stagnant "unless either gas demand increases or the blend rate goes up" (Loveday, 1). Should the blend rate remain unchanged or if E85 cars do not become more prominent, it is possible that the magnitude of ethanol's beneficial effect on obesity will peak in the near future.

The ethanol industry is driven by innovation. New technologies have continually improved the rates of which corn is converted to ethanol. In 1984, 2.40 gallons of ethanol could be derived from a bushel of corn; in 2014, we expect this rate to jump to 3.36 gallons per bushel (Cooper, 3). As the efficiency of ethanol production continues to improve and as ethanol's "blend wall" is approaching, the demand for corn is likely to decelerate or even decrease. Consequently, ethanol production is likely to have diminished effects on other markets and the favorable effect that ethanol has on obesity may be reduced as well.

A significant amount of discussion has recently taken place regarding Brazilian sugarcane-ethanol as a viable alternative to domestically produced corn-ethanol. "It is well known that the U.S. corn-based ethanol industry is relatively inefficient compared to the Brazilian ethanol complex that is based on sugarcane" (Serra et al, 43). Should trade tariffs between the U.S. and Brazil be removed, Brazil is likely to become the preferred source of ethanol in the U.S. The effect of this would lower U.S. demand for corn. Elobeid and Tokgoz (2008) write, "With open borders, the impact of ethanol expansion on crop, feed, and food prices would be mitigated by increased trade" (930). Assuming all other factors remain constant, the importation of Brazilian ethanol would eliminate the favorable effects the U.S. corn-ethanol has had on obesity in recent years.

Under a strict ceteris paribus perspective, a decrease in corn prices might lead to an increase in obesity within the United States. However, there are many other factors that influence the relationship between corn prices and the ethanol industry. In this regard, future research is needed to assess the transmission of ethanol production to food markets, and in turn, its impact on America's obesity epidemic.

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Appendix A
Data

Table 1: Summary Statistics

Monthly Data: 1982.01-2011.05

	Mean	**Median**	**St. Dev**
Ethanol Prices	1.50	1.35	0.47
Corn Prices	2.60	2.38	0.84
Meat Prices	147.78	146.2	34.45
"Unhealthy" Foods	143.47	145.46	27.98
"Healthy" Foods	184.78	184.1	57.52
Relative Food Prices	1.26	1.27	0.16

Annual Data: 2005-2010

	Mean	**Median**	**St. Dev**
Obesity	22.06	22.4	3.93
Big Mac Prices	2.86	2.62	0.49

Figure 1: Annual Percent Change of the Price of Corn: Histogram and Summary Statistics, 1982.01-2011.05

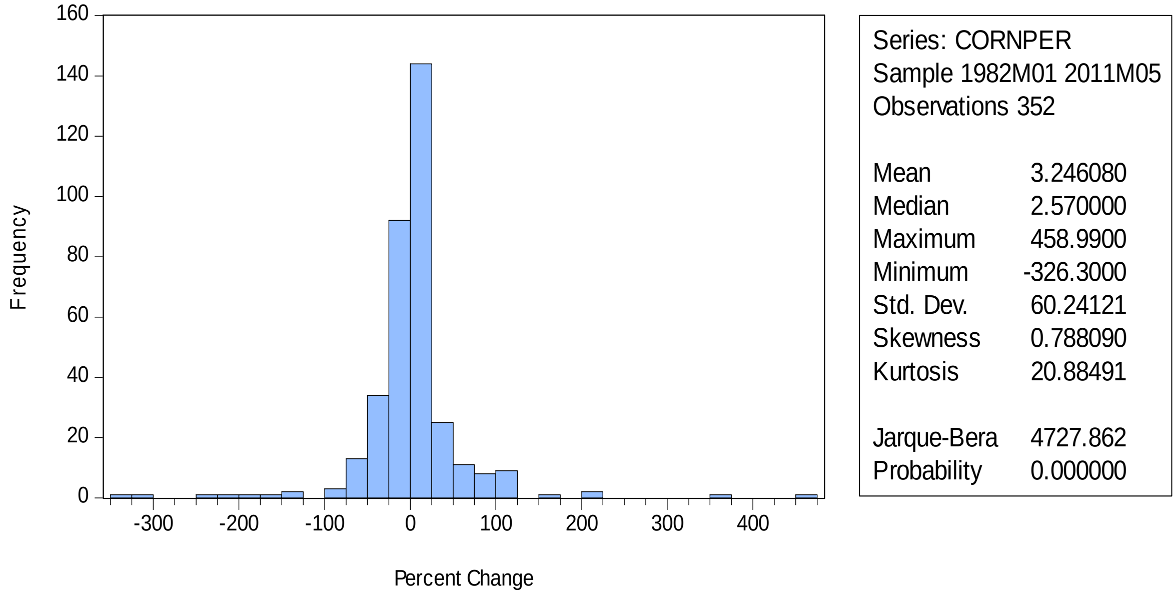
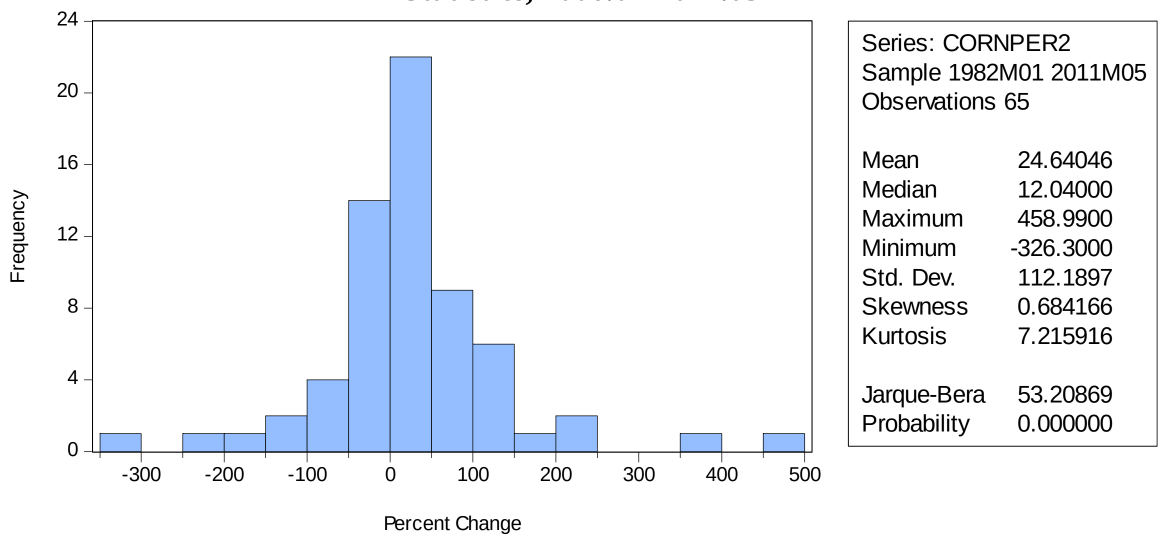


Figure 2: Annual Percent Change of the Price of Corn: Histogram and Summary Statistics, 2006.01-2011.05



Appendix B
Regression Estimations

Table 1: Unit Root Tests

Null Hypothesis: VARIABLE has a unit root

Variable	t-Statistic	Prob.
Ethanol Prices	-2.31	0.17
Corn Prices	-1.32	0.62
Meat Prices	1.24	0.99
Relative Food Prices	-1.27	0.65

Number of Observations: 352

Table 2: Cointegration Tests, 1982.01-2011.05

Dep. Variable	Ind. Variable	Coefficient	Adj. R-Squared	DW Stat	Prob.
Corn	Ethanol	1.150	0.330	0.098	0.0000
Meats	Corn	20.250	0.213	0.014	0.0000
Rel_Food	Corn	0.067	0.116	0.033	0.0039

Number of Observations: 352

Table 3: Cointegration Test, 2006.01-2011.05

Dep. Variable	Ind. Variable	Coefficient	Adj. R-Squared	DW Stat	Prob.
Meats	Corn	8.369	0.695	0.191	0.0000

Number of Observations: 65

Table 4: OLS With Intercept Dummy and Slope Dummy, 1982.01-2011.05

Dep. Variable	Ind. Variable	Coefficient	Adj. R-Squared	DW Stat	Prob.
Rel_Food	Corn	0.025	0.976	1.816	0.0701

Number of Observations: 352

Table 5: OLS Tests, 1995-2011

Dep. Variable	Ind. Variable	Coefficient	Adj. R-Squared	DW Stat	Prob.
Obesity	Rel_Food	41.675	0.888	0.714	0.0000
*Obesity	Rel_Food	9.777	0.985	2.873	0.0282
Ethanol	Obesity	6.179	0.607	0.886	0.0002

Number of Observations: 16

*Regression uses Cochrane-Orcutt Procedure (15 observations)

Table 6: Correlation Coefficient, 1982.01-2011.05

	Corn	Meats
Corn	1	0.470
Meats	0.470	1

Table 7: Correlation Coefficient, 2006.01-2011.05

	Corn	Meats
Corn	1	0.841
Meats	0.841	1

Table 8: Correlation Coefficient, 1995-2010

	Rel_Food	Obesity
Rel_Food	1	0.946
Obesity	0.946	1

Table 9: Correlation Coefficient, 1995-2010

	Big Mac	Corn	Ethanol
Big Mac	1	0.668	0.817
Corn	0.668	1	0.549
Ethanol	0.817	0.549	1