JÖNKÖPING INTERNATIONAL BUSINESS SCHOOL
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# Maize and sugar prices: the effects on ethanol production

Bachelor Thesis in Economics

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# Abstract

The world is experiencing yet another energy- and fuel predicament as oil prices are escalating to new hights. Alternative fuels are being promoted globally as the increasing gasoline prices trigger inflation. Basic food commodities are some of the goods hit by this inflation and the purpose of this thesis is to analyse whether the higher maize and sugar prices are having any effect on the expanding ethanol production. This thesis focuses on the two major crop inputs in ethanol production: maize (in the US) and sugar cane (in Brazil). Econometric tests using cross-sectional data were carried through to find the elasticities of the variables. The crops prices were tested against ethanol output using the log-linear model in several regressions to find a relationship. In addition, the output levels of the crops were tested using the same method. It was found that maize prices and output affects ethanol production. Sugar cane prices do not have any significant impact on ethanol production while sugar cane output has a small, yet significant relationhip with ethanol. Consequently, ethanol's rise in the fuel market could be a result of increased maize input, rather than sugar.

## Kandidatuppsats i Nationalekonomi

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| **Titel:** | Majs och sockerpriser: etanolproduktionens följder. |
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# Sammanfattning

Dagens värld upplever ännu ett energi- och bränsle predikament när oljepriser eskalerar mot nya höjder. Alternativa bränslen marknadsförs globalt samtidigt som de stigande bensinpriserna stimulerar inflationen. Några av de varor som drabbas av denna inflation är grundläggande livsmedelsprodukter och syftet med denna uppsats är att analysera huruvida de högre priserna på majs och socker påverkar den expanderande etanolproduktionen. Uppsatsen fokuserar på de två stora grödor som används som insatsvaror vid framställningen av etanol: majs (i USA) och sockerrör (i Brasilien). Ekonometriska tester genomfördes för att erhålla variablernas elasticiteter med hjälp av den cross-sectional data som behandlades. Genom log-linear modellen utfördes det ett antal regressioner för att hitta ett samband mellan grödornas priser och etanolproduktionen. Därutöver genomfördes tester för att hitta sambandet mellan grödornas utbud och etanol med hjälp av samma modell. Det upptäcktes att både pris och utbudet av majs påverkar etanolproduktionen. Sockerrörspriser har ingen signifikant inverkan på etanolproduktionen medan utbudet av sockerrör har en signifikant, om än svag, relation till etanol. Följaktligen kan etanols tillväxt i bränslemarknaden tolkas som ett resultat av en stigande majsinsats snarare än sockerinstats vid etanolframställningen.

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# 1 Introduction

Despite a unanimous expertise stating that the real price of agricultural products has fallen steadily over many decades (Grynberg & Newton, 2007), a new price trend can be distinguished in recent observations. Several basic food commodities have increased in price over the last years and months. "An explosion in demand for farm-grown fuels has raised global crop prices to record highs" (Grunwald, 2008, p.1). The relationship between ethanol- and sugar and maize will be addressed in this thesis. More specifically, the role of maize and sugar, which are the largest crop inputs in ethanol production, in bringing output changes for ethanol will be studied.

Agriculture has always been an important feature of the modern society not only from an economic point of view. During the agrarian society, lives depended on a good harvest. The world of today, integrated and with over 6.6 billion inhabitants, demands an enormous amount of food that needs to be traded and transported to all populated parts of the planet. Food is still our most important production commodity and cannot be replaced by any other good. Therefore, when demand or supply shocks hit the market causing a price increase, all individuals are affected and forced to give up something else to obtain the amount of food necessary. As a result, to study the current price trends of crops is an important feature in agricultural economics because it concerns us all.

When considering that ethanol over the most recent years has entered the fuels market as an important alternative fuel and prices of crops cultivated for its production have risen, one could make assumptions. According to OECD & FAO (2006), the increased ethanol production is a key market element, and a growing driver, in the outcome of the future for commodities. The reason for ethanol's sudden expansion is mainly as a response to oil's increasing price. That said, ethanol is not new in the fuels market. It has been used as a component of gasoline production before. Brazilian ethanol has, for instance, been produced since the 1970s as a fuel (OECD, 2008). Together with the US, Brazil produced 70% of world ethanol (Martines-Filho, Burnquist & Vian, 2006) in 2005 using mainly sugar cane (in Brazil) and corn (or maize, in The United States) as the crop inputs. High voices of concern have already been made public regarding the negative social effects that the increasing demand for ethanol has and that it is not as non-polluting as it first was stated. Nevertheless, its price is cheaper than oil-based fuels. Governments, such as the US', have supported its expansion through several programmes.

Furthermore, when today's environmental issue lies at the top in the world's political agenda, the public opinion puts pressure on governments to find solutions and ethanol is one of them. To study the agricultural sector, its economic impact and implications for the alternative fuels market, should therefore not only concern the producers of these fuels but the public as well. Being a competitor to sugar and maize, ethanol's increasing demand in the world market creates incentives for farmers to cultivate these crops instead of others. Rising prices of the crops, government-subsidized production and an expanding market also accelerates the expansion. According to OECD & FAO, besides the environmental benefits, "expected economic benefits such as reduced dependency on expensive crude oil imports and job creation, and possible social benefits such as higher farm incomes and improved rural economies" (OECD &FAO, 2006, p.47) are drivers for ethanol's expansion in many countries. Still, this is only the optimist view that several public voices have expressed. There is another, not so convinced group that claims mostly negative social, economic and even environmental effects of ethanol's increasing production. However, this thesis will not go into this discussion but instead look at *what* factors that cause the expansion itself and, more specifically, price changes in maize and sugar as the factors being studied.

## 1.1 Purpose

The purpose of this thesis is to analyze how the price of maize and sugar affects ethanol production. In addition, the two crops' output quantities will be tested against ethanol's output quantities to further find a relationship between ethanol and it's crop inputs.

## 1.2 Specification of Problem

What lies behind ethanol's sudden expansion? The answer could simply be stated as a demand increase. But what role do the inputs of maize and sugar have on ethanol's increasing supply? Does the higher crop prices have any negative effect? In order to further answer the question we first need to study the world food market and concentrate on the specific crops of maize and sugar. What are the price trends for these commodities and what factors are influencing them? Later we study the specific case of ethanol in the market, supply and demand, and the connection between these elements with the price trends for the ethanol-producing crops. Since ethanol has relatively few large suppliers in the international market the country selection is limited to these producers. Still, the study will emphasize the global market for all goods.

The aim of this thesis is not to conclude whether ethanol is good or bad. It is simply to study price changes in sugar and maize, two competitors with ethanol, and the eventual impact that the crops have on ethanol output.

## 1.3 Outline

Chapter 1 introduces the topic in question, including the purpose and a more in-depth definition of the problem. The following chapter gives a background to the study. Starting with previous studies in order to understand future analysis, the author introduces the current sugar, maize and ethanol markets focusing on the large producers: Brazil and the United States. Here, it is important to present recent trends and history of the products in demand, supply and prices. Chapter 3 starts to introduce the theoretical framework based on economic theory. At the end of the chapter, the hypothesis is stated. Chapter 4 presents the data collected, it's limitations and some descriptive statistics in order to understand the variables relationship with one another. The regression models and tests are presented and analyzed in chapter 5 where the hypothesis is tested as well. Chapter 6 summarizes the thesis with a conclusion while the final chapter gives suggestions for further studies.

# 2 Background

## 2.1 Previous Studies

Not many papers involving ethanol and commodity prices were found. Below, the most relevant studies are presented.

According to Gudoshnikov (2004), an increase in the blend ratio of ethanol in gasoline from 20 to 26% causes the world price for refined sugar to increase by $3.04-7.58/tonne, whilst export tonnage falls by between 8% and 34% in the short run.

Bowman and Husain (2004) studied the forecasting of commodity prices and found that models including futures prices were more accurate in estimating prices than those that did not, as the judgmental forecasting model, for the fifteen commodities tested, including sugar and maize.

Elobeid and Tokgoz (2006) showed the impact of the commodities in the ethanol market when US domestic and trade distortions was removed. Prices should increase due to higher demand and particularly Brazilian exports should increase. They also conclude that both corn and sugar prices are affected of a rise in ethanol demand.

Finally, when using a very long time series data (from 1900 to 2001) in studying relative commodity prices, Grynberg and Newton (2007) concluded that the relative prices declined with between 0.79% and 1.43% per annum. Over the past 40 years these numbers are even higher as the study shows. The results prove the general opinion among economic scientists that food prices have been falling relative to other goods. Thus the recent trends with rising food prices are an interesting phenomenon to be studied.

## 2.2 World Market Trends in Food Commodities

The prices of basic food commodities has fallen in real terms for a long period (FAO, 2007) but recent interruptions of this long-term trend can be observed. The price of wheat has, for instance, risen to over $400 a ton (IMF, 2008), twice the average of the past 25 years (Cheap no more, 2007). In past years retail prices have increased, not farmers output price because the raw material is only a portion of the final product cost (National Farmers Union, 2007). Depending on the input share of corn or white sugar for example, some final products rise less in price than others, like a box of corn flakes or soda for instance (Leibtag, 2008).

Increased food prices are normally a respond of crop failure resulting in scarcity but the world of today has no supply shortage, on the contrary, a very abundant grain supply. According to FAO (2007), corn and sugar are among the commodities where global output growth outweighs population growth. Many point out world economic expansion and the role of China and India in explaining the price responses to food demand as income per-capita keeps improving in the world (OECD & FAO, 2006). Especially meat consumption has increased causing a rise in demand for cereals such as corn to feed the livestock. According to Sneller & Durante (2007), this theory should nevertheless be rejected when studying the sudden price shocks of food as the transition for the meat demand has been slow and under a constant rate while the new price-trends are recent. An important factor contributing to the overall rise in food prices are weather patterns causing bad harvests (FAO, 2007) but this should not be considered as a determinant factor to study in this thesis since it is not interested in why prices are rising but rather its effect on ethanol output quantities. The world trade quantities of food compared to other manufactured products have fallen in recent decades (FAO, 2007). Nevertheless, output growth remains strong especially in OECD countries and emerging markets (OECD & FAO, 2006).

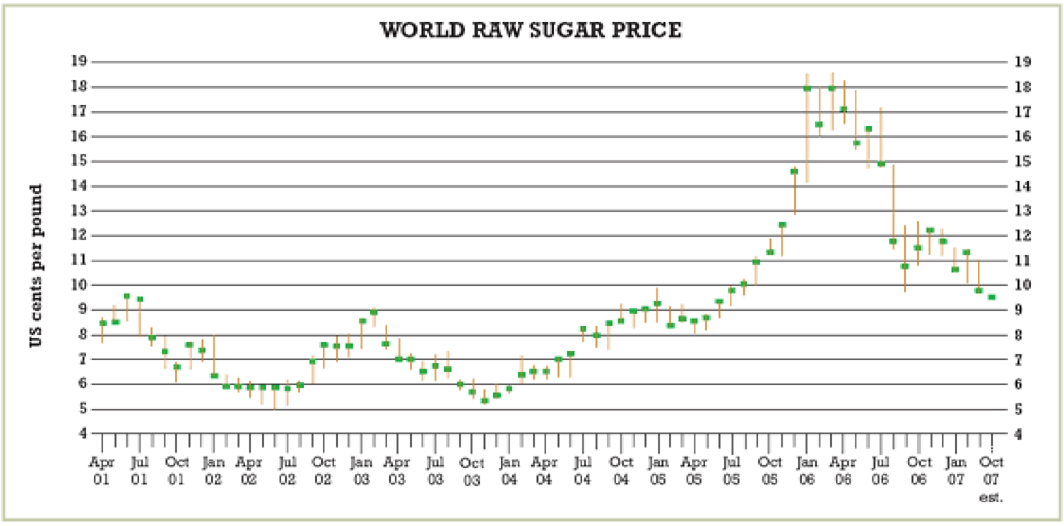
### 2.2.1 The International Maize Market

Recently, American farmers have seen an unusual uprisng price-trend in the maize market, parallel to demand increases for ethanol and other biofuels. The US is the leading producer of maize and when the ethanol programme was expanded in 2005 (Katz, 2008), farmers switched to the more lucrative maize production resulting in price increases for the replaced crops. Many of the crops, including maize, are largely used to feed the livestock that eventually results in meat, an increasing demand commodity in the world. Other factors, such as the decreasing dollar rate and oil price increases has affected the maize prices (Katz, 2008) when the US, being the largest producer and exporter, trades maize in the international market. The maize price in the world market has had an ascending price trend in recent years, more than doubling the price per ton in the first quarter of 2008 compared to 2005 (IMF, 2008).

### 2.2.2 The International Sugar Market

Sugar prices are considered one of the most volatile among commodities in international trade (Gudoshnikov, 2004) and can be observed in figure 1:

Figure 1: Volatility in the sugar market




Source: Illovo Sugar Statistics, 2007

Price stability in earlier years could have been the result of trade liberalization and deregulations, world demand fluctuations and policy reforms. In 1975, the international market experienced decreasing prices in sugar, which peaked in variability during this period. By the late 1990s, the sugar industry suffered a recession following from record production levels and falling prices. According to the IMF (2008), the free market's sugar price rose to 14.8 cts/lb in 2006, decreased to 10.0 cts/lb during 2007 and reached 13.6 cts/lb in the third quarter of 2008, numbers that goes in line with the volatility statement.

World per capita consumption of sugar has not seen any dramatic changes since the 1970s and in fact, almost all of the sugar demand increase since then come from developing countries. Mainly Asias demand is notable and Russia is now the leading importer of sugar (Gudoshnikov, 2004). FAO (2007) refer to biofuel's demand increase when explaining the recent accelerating production growth- and demand trends of sugar. Supply has risen since the mid-1990s, as well as world import demand since the beginning of that decade. Particularly Brazil has shown output increases for sugar as the quantity rose by 95% from the period 1991-93 to 1999-2001 (Gudoshnikov, 2004). In 2005-2006, Brazil produced 25% of the worlds sugar cane (OECD, 2008) and since the 1990s it is the largest exporter of sugar, reaching 40% of world exports in 2006 (OECD & FAO, 2006). Other important exporters are the EU, Australia, Thailand and Cuba (Gudoshnikov, 2004). Despite the increase in world demand, a limited number of producers are present. Over the years, sugar originating from cane has slowly replaced beet sugar as the main source in the market and accounts today for 83% of the world's total sugar production (Grynberg & Newton, 2007).

## 2.3 World Ethanol Production and Demand

Global biofuel production reached a new peak in 2007 and between 2000 and 2005, world production grew at a rate of 13% per year (Martines-Filho et al. 2006).

In the 1980s, as a response to decreasing oil prices and price spikes in the international sugar market, ethanol experienced credibility loss and supply shortage (OECD, 2008). Since the millennium shift, an ethanol expansion has been present due to higher oil prices and ethanol demand. The future demand for ethanol is to increase further in the fuels market.

Much of the upward supply trend is a consequence of policy implementations. Several countries have introduced higher ethanol-concentrated gasoline. The EU, for instance, has set up the goal of having 5.75% blend of ethanol in the gasoline by 2010, and in Sweden tax breaks and special parking privileges are offered for flex-fuel cars (Martines-Filho et al. 2006). The explosion in demand for farm-grown fuels has raised global crop prices resulting in an expansion of ethanol-producing countries' agriculture. As a result, deforestation and hunger (crops used for fuel-production rather than food) in developing countries are some effects when biofuels enter the market. Ethanol production has therefore been criticized when studying the social and environmental effects of a rise in demand (Grunwald, 2008).

Sugar cane and maize are the leading crops used as inputs in ethanol production today. According to Carvalho (2002), the future demand for crops when producing ethanol will depend on “the competitiveness degree of the raw materials, the availability and potential of the lands for production, and the global and national public policies implemented” (Carvalho, 2002, p. 2). After Brazil and USA, there exists a gap to the other large producers; China, EU and India. This will be illustrated later in table 1 in chapter 4.

### 2.3.1 Brazilian-produced Ethanol

Brazilian ethanol production as a gasoline additive dates back to the 1920s (Carvalho, 2002) but it wasn’t until the 1970s when the oil crises hit the fuels market that the alcohol increased in supply, mainly for the domestic fuels market. Rising oil prices forced the military government to introduce alternative fuels programmes and ethanol production from sugar cane was an attempt to stabilize the economy. Since 1997, both sugar cane and ethanol prices are determined by market forces and government intervention has been reduced. Today, only some small interventionist policies remain.

Brazil as a producer has a comparative advantage in production, making the price appealing to foreign buyers. The total cost of production during 2005 was approximately $1.10 per gallon (0.89 variable cost and 0.21 fixed cost) while the US’ total ethanol production cost lay between $2.01 and $3.96 per gallon (0.96 variable cost and fixed cost range from 1.05 to 3.00) (Martines-Filho et al. 2006). According to Ethanol Statistics (2008), the price of Brazilian ethanol was $1.850 per gallon in April 2008 compared to $2.550 for US produced ethanol during the same period.

The success and growth of Brazilian ethanol is much due to investments in R&D which ultimately is financed through the government. One of the negative outcomes is the mass unemployment among the 1.2 million sugar cane workers as a result of the environmental policies such as the burning law (see Martines-Filho et al. 2006). In 2005, more than half of the total sugar cane production was used to produce ethanol and 38% of the cars sold were flex-fuel cars (Martines-Filho et al. 2006). Since 2003, Brazil has seen an impressive rise in ethanol exports mainly to the US (see OECD stat, 2007).

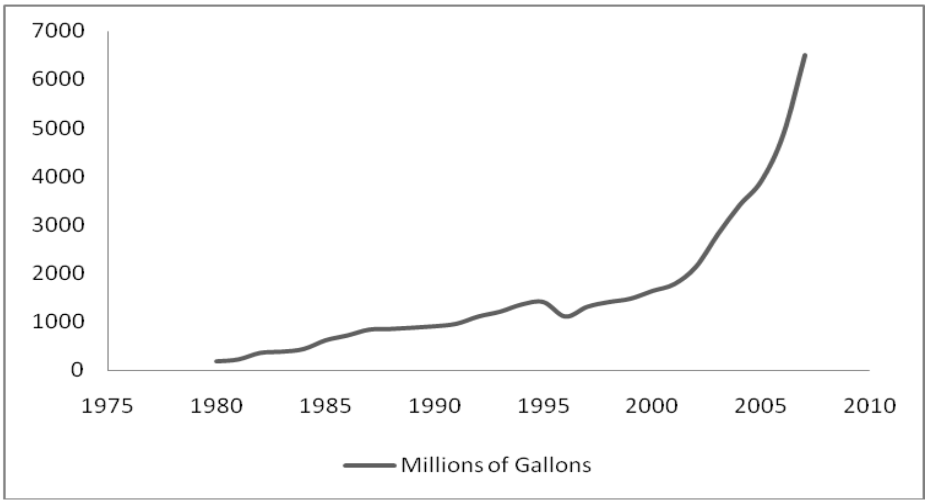
### 2.3.2 US-produced Ethanol

In 2005, the US surpassed Brazil as the world’s largest ethanol producer (Swedish Trade Council, 2008). US government support, such as subsidies, for ethanol producers are the reason to the historical shift.

It is expected that maize will continue to be the primary source of ethanol in the coming decade although the recent ethanol price reductions and maize price increases could bring investments to alternative feedstocks for ethanol production. In 2006, about 18.5% of the US maize was used for ethanol (Sneller & Durante, 2007) and 92% of the ethanol production was maize-based (Swedish Trade Council, 2008). Still, much of the maize is for livestock feed which now competes with ethanol for the corn and as a result, a price effect on meet occurs when maize prices increase. In the 2006/2007 crop year, a 30% increase in ethanol production from the harvested maize crop was recorded in comparison to the previous year (Leibtag, 2008). Still, the US imports a substantial amount of ethanol despite import tariffs. 13% of demand in 2006 was imported to meet the growing hunger for the product (Swedish Trade Council, 2008).

Higher maize prices have been observed since the introduction of the ethanol programme in 2005 and several economic gains (since ethanol production is subsidized) are reachable for American farmers if they increase the total ethanol production. The result of the ethanol programme also quickly launched incentives for farmers to increase the maize crop fields and to turn into maize production instead of other crops. To get a clear view of ethanol's emergence in the fuels market it is appropriate to study the US output over time as presented in figure 3:

Figure 2: Historical U.S. fuel ethanol production since 1980




Source: RFA, 2006

From figure 3 we can see how rapidly ethanol as a fuel has expanded in the US and increased with as much as 1.645 million gallons in 2007 as compared with the previous year (RFA, 2006).

# 3 Theory

## 3.1 Assuming Perfect Competition

When the agricultural sector was studied, perfect market conditions were assumed to hold. The farm sector is the sector in the economy that comes closest to fulfill the requirements for perfect competition. According to Penson, Capps and Rosson (2002), and as basic economic theory teaches us, there are four conditions to be fulfilled if perfect competition is to hold:

- The products sold by businesses are perfect substitutes, buyers in the market can choose from a number of sellers.
- Firms and resources must be free to enter and leave the sector without any serious barriers.
- Each seller is a price taker, no firm has more influence on setting the price than others and there are a large number of sellers.
- Perfect information prevails for buyers and sellers.

The maize and sugar markets are both close to perfect competition. Suppliers of the products are perfectly competitive and are, by definition, price takers. The ethanol's market is different in this matter since its production is often subsidized, firms need licenses and technology to enter the market, there are a limited number of producers and perfect information is not overwhelmingly present.

## 3.2 Demand, Supply and Market Equilibrium

Once perfect competition conditions are prevalent in the market we can define the market equilibrium; price and quantity, demand and supply.

A market working under perfect competition determines the price and quantity in equilibrium, e.g. where demand equals supply. An increase in demand results in a price and quantity supplied increase. In our case, a price increase in sugar or maize should lower ethanol production, all other things being equal (Penson, Capps and Rosson, 2002).

Gudoshnikov (2004) states that the major drivers for sugar consumption (demand) are population growth and per capita consumption changes. As mentioned in section 2.2.2, per capita consumption patterns are minimal as world population growth and sugar consumption both have increased at a smooth relative rate. Being a commodity that many times is used as a small input in beverages and manufactured food products, price changes in sugar are barely noticeable for consumers. Ethanol's expansion is however a factor that in theory should be influenced by both sugar and maize equilibrium prices as the crops are used as a larger input during production. Since much of the production of the fuel is subsidized, ethanol output rises as not only the demand for the crops are increased but also farmers' income.

There is an important aspect to consider when analyzing the supply side of the agricultural market; price setting and production. Because crops are season and weather dependent, planning is not an easy task for farmers and there is often no certainty about what price will be received when the product is ready to be sold. The products are not ready for sale until months after the date of seed and therefore producers either have a forward contract or use a futures market to determine the price of the product, unless there is a fixed price set by the government (Schrimper, 2001). As a result, price setting and quantity supplied in the market are very much driven by expectations. It is therefore not certain that all crops will be put in the market for sale if the farmer does not find it profitable to sell everything at this time but instead stocks the surplus. Thus, today's abundant grain supply discussed in section 2.2 is partly explained by this phenomenon.

Both sugar and maize are generally traded in future contracts in the international market. The contracts are set mutually by buyers and sellers for a future exchange of the products. Among the most active commodity Futures exchanges currently are the *Chicago Board of Trade* (CBOT) for maize, and the Coffee, Sugar and Cocoa Exchange (CSCE) in the *New York Board of Trade* (NYBOT) for sugar (Geman, 2005). The first sugar contracts in the CSCE dates back to 1914 according to Geman (2005).

## 3.3 Cross-price Elasticity of Demand

For this thesis purpose it is necessary to understand the relationship price vs. demand for the products in focus. If we are to study the supply effect of ethanol when sugar and maize prices change we need to work with elasticities to find the relationship. When studying the effects that a change in the price of one good can have on the demand for another good we can use cross-price elasticity:

$$\text{Cross-price elasticity of demand} = \frac{(Q_{AA} - Q_{AB}) \div ([Q_{AA} + Q_{AB}]) \div 2)}{(P_{BA} - P_{BB}) \div ([P_{BA} + P_{BB}] \div 2)} \qquad (1)$$

in which $Q_{AA}$ and $Q_{AB}$ refers to the quantity of good A after and before the change, respectively. $P_{BA}$ and $P_{BB}$ are the prices of good B after and before the change. In simple terms, cross-price elasticity may be written as:

$$\text{Cross-price elasticity of demand} = \frac{\text{percentage change in quantity of good A}}{\text{percentage change in price of good B}} \qquad (2)$$

If the resulting cross-price elasticity is positive the goods are substitutes, if it is negative the goods are complements and if elasticity is zero the goods are independent (see Penson, Capps. & Rosson, 2002). What normally determines the size of the price elasticity of demand for a good is the product's degree of substitutability for other products (Schrimper, 2001).

## 3.4 Measuring Elasticity: the Log-Linear Model

In this thesis, the main purpose is to find whether there is a relationship between ethanol and its two major crop inputs: maize and sugar. To see if ethanol's production quantity indeed is affected by the both crops price variations, the most appropriate way to measure the degree of this impact was to find the elasticities. The log-linear model is linear in both the parameters and in the logarithms of the variables (Gujarati, 2003). The model was used in the two-linear regression models (one independent variable) and in the multiple regression models (two independent variables) where sugar cane and maize were the independent variables. All data is cross-sectional and tested for single- and multiple (2-3) years. In addition, besides the price effects of sugar and maize on ethanol output, the crops output effects on ethanol production was also tested. This in order to get a more truthful answer regarding maize and sugar's role in bringing ethanol output changes. The coefficient(s) will measure the elasticity(s) of ethanol with respect to the variable(s) sugarcane and/or maize. That is, if for example maize prices increase by 1%, the corresponding percentage change in ethanol production will be discovered.

## 3.5 Hypothesis

The following null and alternative hypothesis will be tested:

$H_0$ : Sugar cane and maize prices does **not** have a significant effect on ethanol demand and production. More specifically, the relationship **does not exist**.

$H_1$ : Sugar cane and maize prices have a significant effect on ethanol demand and production. More specifically, the relationship is **negative**.

# 4 Data and Descriptive Statistics

## 4.1 Data Limitation and Future Regressions

For all data collected and tested, the use of *sugar cane* instead of sugar were found more appropriate due to accessibility and relevance. Sugar cane is the crop that later will be processed into the final product sugar.

It is important to mention the difficulty in finding appropriate data in order to run time series regressions. Especially ethanol data was difficult to obtain and it was only US supply that could be found over time (1980-2005) for an individual country. Consequently, regressions using time series data will not be tested in this thesis. Eventually, ethanol production quantities for 33 countries were found for the years 2004-2006 but no price data. Maize and sugar cane production quantities and prices were easier to find although 2006 prices by country was not located. Regression models to test the elasticities for ethanol production with respect to maize and sugar cane prices for the 33 countries during the years 2004-2005, was tested. Furthermore, the variables output was also tested for the years 2004-2006 to analyze the relationship between ethanol production – maize and sugar cane production. To obtain a final conclusion, if possible, the use of cross-section data using all 99 observations for both output and price may give some answers. Three tests will be run for the output (2004, 2005, and 2006) and two for the crop prices (2004, 2005). The number of observations will nevertheless be reduced as many ethanol producers do not have significant sugar cane production. In all regression models, the dependent variable will be ethanol with sugar cane and/or maize as independent variable(s).

## 4.2 Descriptive Statistics

The following table containing the world's 10 leading ethanol producers in 2006 has been constructed. This in order to see and understand ethanol's relationship with maize and sugar cane. Production quantities are from 2006 while prices, usually more difficult to obtain, show numbers from 2005.

Table 1: Leading ethanol producers and their respective maize and sugar cane quantities and prices

| Country | Ethanol production (millions of gallons) | Maize production (millions of tons) | Sugar cane production (millions of tons) | Maize producer price (US$/tones) | Sugar cane producer price (US$/tones) |
|---|---|---|---|---|---|
| USA | 4,855 | 267.6 | 26.8 | 78.00 | 31.00 |
| Brazil | 4,491 | 42.6 | 455.3 | 69.15 | 13.99 |
| China | 1,017 | 145.6 | 100.7 | 115.95 | 43.77 |
| India | 502 | 14.7 | 281.2 | 120.22 | 65.99 |
| France | 251 | 12.9 | N/A | 132.30 | N/A |
| Germany | 202 | 3.2 | N/A | 119.59 | N/A |
| Russia | 171 | 3.7 | N/A | 84.44 | N/A |
| Canada | 153 | 9.3 | N/A | 90.01 | N/A |
| Spain | 122 | 3.5 | 0.05 | 168.18 | 44.85 |
| South Africa | 102 | 6.9 | 20.3 | 178.73 | 29.28 |

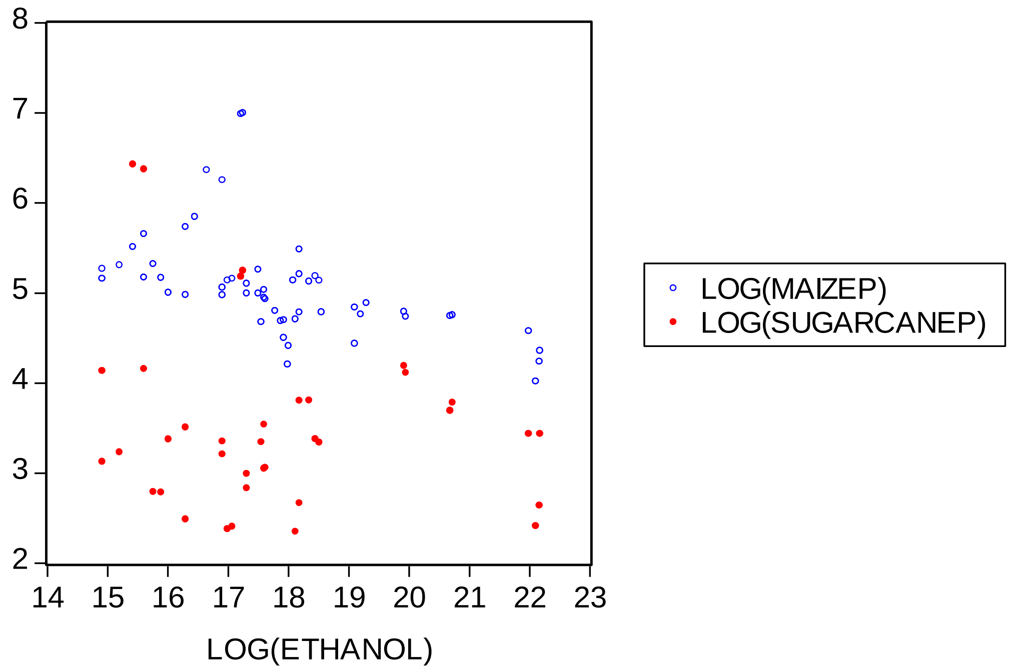
Source: FAO 2007; RFA (2006)

Table 1 proves the US and Brazil dominance when producing ethanol, maize and sugar cane. Here, it is important to note that the ethanol data covers all grades, that is, ethanol for all use, including fuel. World *fuel* ethanol production for the two countries was almost 88% of world output in 2007 (RFA, 2006). Prices are measured in $/tone and are the producer prices. The table also displays the few sugar cane producers that are present. China and India are, after Brazil, the world's largest suppliers of the crop. Some of the greatest suppliers of ethanol, such as France and Canada, lack significant numbers of sugar cane prices and quantities. Sugar cane production is mainly concentrated to areas with a warm and humid climate according to the whole FAO data set. So why are there countries producing ethanol while not having any sugar cane production and small maize production? Most of the crops used as inputs in ethanol production are imported in these countries but one should bear in mind that ethanol is often produced through a fermentation process of sugar. Sugar can also be obtained from other crops, besides sugar cane and maize (RFA, 2007) and can explain the situation. In addition, government-subsidized production of ethanol has intensified, making producers less dependent on market factors such as price and supply of the crops during production.

Because of the general data limitation over time, the regressions are based on price and output from the years 2004, 2005 and 2006 for the 33 largest ethanol producers. The numbers of observations vary according to the data that was found. For instance, all ethanol data is based on the 33 countries whereas sugar cane output in 2004 only include 21 observations since many of the ethanol producers do not have any significant sugar cane production, as mentioned earlier. Thus, when comparing the numbers over different years it is important to note this. Since this thesis will not take into account time the variables growth numbers do not play a major role when analyzing the relationship between ethanol and maize/sugar cane.

In order to get a better view of the relations among the variables, the following scatter plot was created:

Figure 3: Relationship among the dependent variable and the independent variables




The scatter plot is created from the results using cross-section data including 37 observations for the years 2004 and 2005. Maize and ethanol have a minor negative relationship whereas sugar cane prices tend to be very volatile. The price volatility for all sugar explained by Gudoshnikov (2004) seems to concur with the results.

# 5 Empirical Findings and Analysis

## 5.1 Regression Models

As mentioned in section 3.4, the log-linear regression model was tested using several combinations of the independent variables. Using cross-section analysis is practical since we do not have data covering more than three years. Below, equation 1 illustrates one combination where prices of both sugar cane and maize for one of the years 2004, 2005 were tested:

$$\ln Y = \alpha + \beta \ln P_M + \gamma \ln P_S \qquad (3)$$

Y = Quantity of ethanol

$P_M$ = Price of maize

$P_S$ = Price of sugar cane

$\beta$ and $\gamma$ are the elasticity coefficients to be estimated

Regressions using one of the independent variables (simple regressions) were also tested. This may give a more precise result for the maize data, which is larger than the sugar cane data. Two more tests including data from the years 2004-2005 were also carried through to include more observations. Ethanol output was used as the dependent variable in all regressions throughout this thesis.

In addition, and in line with the purpose, *production* quantities for maize and sugar cane was tested against ethanol production quantities to find a relationship. The same log-linear model in equation 3 above was used, with the difference of plugging output numbers rather than prices. As in the regressions using prices, the independent variables will be tested separately and together, as well as the use of all data for the period of 2004-2006 in one regression. The difference will be that data for one more year (2006) is available. All the regressions, whether they are simple regressions or multiple regressions, measures elasticities and entail cross-sectional (data is from the same point in time) data.

## 5.2 Regression Results

Table 2: Multiple regression results for the years 2004-2006
*Dependent variable: ethanol production*

| Year / Variable | 2004 | 2005 | 2006 | 2004-2005-(2006) |
|---|---|---|---|---|
| Maize price | -2.231** | -2.275** | - | -2.250*** |
| (t-stats.) | -2.641 | -2.320 | - | -3.675 |
| Sugar cane price | 0.335 | 0.198 | - | 0.269 |
| (t-stats) | 0.671 | 0.345 | - | 0.750 |
| $R^2$ | 0.324 | 0.303 | - | 0.312 |
| F-value | 3.831 | 3.262 | - | 7.719 |
| Observations | 19 | 18 | - | 37 |
| Maize output | 0.226* | 0.238** | 0.252** | 0.239*** |
| (t-stats.) | 1.874 | 2.099 | 2.242 | 3.784 |
| Sugar cane output | 0.267 | 0.293 | 0.267 | 0.277** |
| (t-stats) | 1.130 | 1.286 | 1.154 | 2.181 |
| $R^2$ | 0.337 | 0.367 | 0.386 | 0.365 |
| F-value | 4.316 | 5.514 | 5.960 | 17.522 |
| Observations | 20 | 22 | 22 | 64 |

*=Significant at 10% level
**=Significant at 5% level
***=Significant at 1% level

All variables are measured in the same units as in table 1. The results above only show the multiple regression results. In total, 7 were carried through. Given the different numbers of observations for every regression, the t-critical values will not be presented in this thesis. Naturally, they were all calculated and tested against the t-values for all regressions but a detailed written evaluation of them would be too long to fit in this thesis. Below in table 3, the results from a total of 10 regressions using one independent variable are presented and as in table 2, the numbers of observations vary which makes the presentation of the t-critical values too long to be presented here.

Table 3: Simple regression results for the years 2004-2006
*Dependent variable: ethanol production*

| Year / Variable | 2004 | 2005 | 2006 |
|---|---|---|---|
| Maize price<br>(t-stats.) | -1.625***<br>-3.171 | -1.639***<br>-3.172 | -<br>- |
| $r^2$ | 0.279 | 0.287 | - |
| F-value | 10.054 | 10.060 | - |
| Observations | 28 | 27 | - |
| Sugar cane price<br>(t-stats.) | -0.353<br>-0.713 | -0.517<br>-0.946 | -<br>- |
| $r^2$ | 0.029 | 0.053 | - |
| F-value | 0.509 | 0.895 | - |
| Observations | 19 | 18 | - |
| Maize output<br>(t-stats.) | 0.293***<br>3.442 | 0.308***<br>3.709 | 0.320***<br>3.955 |
| $r^2$ | 0.297 | 0.322 | 0.350 |
| F-value | 11.850 | 13.758 | 15.644 |
| Observations | 30 | 31 | 31 |
| Sugar cane output<br>(t-stats.) | 0.496**<br>2.292 | 0.518**<br>2.379 | 0.525**<br>2.396 |
| $r^2$ | 0.217 | 0.220 | 0.223 |
| F-value | 5.254 | 5.658 | 5.741 |
| Observations | 20 | 22 | 22 |

*=Significant at 10% level
**=Significant at 5% level
***=Significant at 1% level

## 5.3 Hypothesis Testing and Analysis

This first part of this section will analyse the results from the multiple regressions illustrated in table 2. Later, the simple regressions will be analysed. Recall from chapter 3 that $H_0$ in this thesis assumes that there is *no* relationship between the crops prices and ethanol output. For 19 and 18 ethanol producing countries that had both maize and sugar cane production in 2004 and 2005 respectively, the relationship exists for ethanol and maize but not for ethanol and sugar cane. Thus, we can reject $H_0$ for maize prices but cannot reject $H_0$ for sugar cane prices.

The tests of the output of the independent variables show that ethanol and sugar cane have a small relation whereas maize tends to have a more close relationship with ethanol. However, when adding all years together to obtain more observations, all variables except that of sugar cane prices are significant at the 5% level. This implies a possible existing relationship between the variables and a strong relationship for ethanol and maize. Also, the F-values are all relatively high (as compared to the t-statistics) and are significant when tested against their respective values from the F-distribution table.

Unfortunately, one can question how realistic the results of the elasticities are. Even if the p-value of the maize prices are significant at the 5% level, the elasticities show unrealistic values. For example, the price elasticity of -2.231 for maize in 2004 means that if the maize price would increase by 1% then ethanol production would decrease by 2.231%, all else equal. This is in line with what was expected when an inputs price changes (Penson, Capps and Rosson, 2002). An important detail in the thesis is the fact that no other variables are tested. For instance, other factors such as economic growth, policies or weather patterns are not included here. Thus the elasticities are not showing the whole truth about the actual impact that maize and sugar cane have on ethanol production.

When testing the two independent variables separately (in the simple regressions illustrated in table 3) the results turn out the same, that is, reject $H_0$ for maize but not for sugar cane and there is a negative relationship between ethanol production and maize prices. The F-values are all significant with the exception of sugar cane prices. The output-output t-values are however all significant at the 5% level, even with sugar cane. It could be said from this simple observation that ethanol is more sensitive to output variations of the crops, rather than prices. Also here, the elasticities tend to be very large, especially the maize prices.

Even if the $r^2$ values of the simple regressions (and $R^2$ for the multiple regressions) are not the most determinant in this case, a discussion concerning the obtained values will be held to find further relationships. Recalling from Gujarati (2003), $r^2$ is limited to a number between 0 and 1. An $r^2$ of 1 means a perfect fit between the variables; whereas an $r^2$ of 0 means that there is no relationship between the variables at all. Especially the case of sugar cane prices in bringing ethanol output changes, the relation is very small as, for instance, the highest $r^2$ obtained was less than 0.03 for 2004 (i.e. only 3% of ethanol's increasing output is explained by the sugar cane price variation!). The highest was 0.29, "Ethanol production-*Maize prices 2005",* appendix 4. No regression reaches 0.3 in their $r^2$ which shows how little the regression line "fits" the data. The output-output relationship seems to show a more positive relation when looking at the $r^2$ values but also here, the values are rather small. When studying the multiple regressions in table 2, the $R^2$ ranges between 0.30 and 0.36 approximately. That is, neither maize nor sugarcane prices, when studying the $r^2$ and $R^2$ values, tend to have a very significant impact on ethanol production. Again, the $R^2$ values for output are relatively low albeit higher than the prices.

But we must be careful of drawing any rash conclusions. In multiple regressions, testing the F-stat in comparison to the $R^2$, one can more accurately determine whether the $R^2$ results are relevant. The multiple regressions tested here, have both sugarcane and maize as independent variables. In the 7 multiple regressions that was carried out, all except "Ethanol production- *Maize, Sugarcane prices 2005"* (appendix 6) were significant at the 5% level when comparing the F-statistic with it's corresponding value at the F distribution table, meaning that at least one of the variables (maize or sugarcane) is significant. The conclusion on this discussion is that the $r^2$, $R^2$ and F-statistic demonstrates that the relationship between ethanol output and the crops' prices/output is small or insignificant, however, we can reject the null hypothesis. In addition, Gujarati (2003) recognizes that cross-sectional data typically obtains low $r^2$ values and thus the results should not be considered as definite. After all, the p-values are the most important values to be considered when the hypothesis is tested.

Overall, maize (both price and output) tend to show a stronger relationship with ethanol than sugar cane. Fewer observations for sugar cane, the volatile sugar market prices and the rise of maize as the main crop input in ethanol are a few explanations. Not to forget is the US influence where demand for ethanol and maize (as the crop input) is challenging the perfect market conditions of the variables through subsidized production. Ethanol is indeed affected by price- and output changes of maize. Sugar cane output influences ethanol output but the results are not strong enough to be considered as any real evidence. What is clear, however, is that sugar cane prices do not cause any significant ethanol output variations. Furthermore, the output-output relationships are more significant than the output-price relationships. All "*ethanol output – maize/sugar cane prices*" regression results tested are presented in detail in the appendix tables 1-7. In addition, the "*ethanol output – maize/sugar cane output*", were data from all the years (2004-2006) was used in one regression, is also included (appendix 8).

## 5.4 Cross-price Elasticities

In addition to the regressions that were tested in this thesis, the cross-price elasticity of demand model presented in section 3.3 was also calculated. This in order to find additional relationships among the variables. Accordingly, equation 1 was calculated when maize and sugar cane price changes between the years 2004-2005 were used along with the corresponding ethanol output quantities.

This simple model can't really tell us about the actual impact that price changes of the crops may have on ethanol production but it can give a hint towards the direction of the relationship between the variables. The results show opposite outcomes of the variables in relation to ethanol: maize and ethanol are found to be complements (as expected) while sugar cane and ethanol turn out to be substitutes. The results may be different simply because sugar cane prices increased over the period while maize prices decreased. Another explanation could be that sugar cane easily can be replaced by other products to obtain sugar when ethanol is being processed.

The results put further doubt on the initial belief that sugar cane prices have an impact on ethanol production. In line with the regression results, only maize and ethanol show an existing relationship.

# 6 Conclusion

Throughout this thesis, and in line with the purpose, a relationship between ethanol and maize/sugar cane prices was intended to be discovered. Given the intricacy when searching for data (ethanol data specifically), the thesis main purpose could not be analysed as thoroughly as first intended. The ideal scenario would have been to locate a large sample of time series data for all three variables price trends. Then, the price changes of both crops could have been tested against ethanol’s expansion in recent years to find a connection. However, to study current crop price levels in the form of cross-sectional data for the largest ethanol producers gave a reasonable picture about maize and sugar cane’s relation with ethanol. In order to extend the study of the impact that the food commodities actually have in ethanol production, the output-output regressions completed the study.

It is evident from the regressions that ethanol output is affected when maize prices and production quantities change. The relation is stronger when only maize is tested against ethanol. In the case of sugar cane, price variations have no effect on the quantity supplied of ethanol. On the other hand, output changes of sugar cane were found to have significant influence on ethanol output, but only when the commodity was tested independently in the simple regressions. Furthermore, the relationship between the crops prices and ethanol output was found to be negative as expected. That is, when the crops prices increase, ethanol output drops. In addition, a rise in the quantity of maize and sugar cane results in ethanol production growth, a positive relationship.

In summary, it can be said that of the four independent variables tested in this thesis, only sugar cane prices doesn’t seem to affect ethanol production. Moreover, sugar cane’s output relation with ethanol is too small to hold as evidence. Sugar output and demand has not seen any considerable changes as discussed in the background chapter and consequently, the price volatility that accompanies sugar through time cannot explain ethanol’s rise in consumption in recent years. The sudden expansion of US-subsidized ethanol- and maize production can help explain why maize and not sugar cane is influencing ethanol output. The final conclusion can thus state that maize but not sugar is affecting ethanol’s expansion in the market.

# 7 Suggestions for Further Research

Considering the difficulty in finding ethanol data, unless direct access to databases, it would be hard to make studies of ethanol's impact on different sectors of the society using time series. Nevertheless, US data was undoubtly the most accessible so an extensive US ethanol study is fully feasible. Being the largest ethanol supplier in the world the analysis of one individual country like the US could give an indication on ethanol's actual impact and future.

One argument when discussing ethanol is often the negative social effects it can bring. If ethanol really drives up inflation among food commodities, the poorest are hurt seriously. Therefore, a paper analyzing the relationship between ethanol demand and macroeconomic variables would be of interest.

A positive argument for ethanol's expansion in the fuels market is that it reduces the dependency on oil. A number of different studies could be done when studying the increase in ethanol and the effects on oil consumption and dependency.

If ethanol finally is "chosen" as the fuel of the future, research on cost-reduction and profit-maximization would interest producers. Besides economical studies, technological and environmental analysis could increase knowledge about ethanol since ethanol recently has been accepted as a serious competitor in the fuels market and research about the topic is still unfinished.

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# Appendices

## Regression Appendix 1: Ethanol production-*Maize prices 2004*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 28 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZEP) | -1.624957 | 0.512461 | -3.170887 | 0.0039 |
| C | 26.15117 | 2.628284 | 9.949902 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.278870 | Mean dependent var | 17.86722 |
| Adjusted R-squared | 0.251134 | S.D. dependent var | 1.758514 |
| S.E. of regression | 1.521766 | Akaike info criterion | 3.746369 |
| Sum squared resid | 60.21005 | Schwarz criterion | 3.841526 |
| Log likelihood | -50.44917 | F-statistic | 10.05452 |
| Durbin-Watson stat | 0.646934 | Prob(F-statistic) | 0.003872 |

## Regression Appendix 2: Ethanol production-*Sugarcane prices 2004*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 19 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(SUGARCANEP) | -0.353066 | 0.494866 | -0.713457 | 0.4852 |
| C | 18.98476 | 1.774180 | 10.70058 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.029072 | Mean dependent var | 17.76749 |
| Adjusted R-squared | -0.028041 | S.D. dependent var | 2.091760 |
| S.E. of regression | 2.120885 | Akaike info criterion | 4.440845 |
| Sum squared resid | 76.46863 | Schwarz criterion | 4.540260 |
| Log likelihood | -40.18803 | F-statistic | 0.509021 |
| Durbin-Watson stat | 0.159656 | Prob(F-statistic) | 0.485243 |

## Regression Appendix 3: Ethanol production- *Maize, Sugarcane prices 2004*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 19 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZEP) | -2.231209 | 0.844923 | -2.640725 | 0.0178 |
| LOG(SUGARCANEP) | 0.334789 | 0.499065 | 0.670831 | 0.5119 |
| C | 28.01771 | 3.745661 | 7.480043 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.323791 | Mean dependent var | 17.76749 |
| Adjusted R-squared | 0.239264 | S.D. dependent var | 2.091760 |
| S.E. of regression | 1.824436 | Akaike info criterion | 4.184359 |
| Sum squared resid | 53.25709 | Schwarz criterion | 4.333480 |
| Log likelihood | -36.75141 | F-statistic | 3.830655 |
| Durbin-Watson stat | 0.881166 | Prob(F-statistic) | 0.043717 |

## Regression Appendix 4: Ethanol production-*Maize prices 2005*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 27 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZEP) | -1.638589 | 0.516633 | -3.171670 | 0.0040 |
| C | 26.13573 | 2.623085 | 9.963736 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.286926 | Mean dependent var | 17.87320 |
| Adjusted R-squared | 0.258403 | S.D. dependent var | 1.850014 |
| S.E. of regression | 1.593158 | Akaike info criterion | 3.840501 |
| Sum squared resid | 63.45381 | Schwarz criterion | 3.936489 |
| Log likelihood | -49.84676 | F-statistic | 10.05949 |
| Durbin-Watson stat | 0.633746 | Prob(F-statistic) | 0.003983 |

## Regression Appendix 5: Ethanol production-*Sugarcane prices 2005*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 18 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(SUGARCANEP) | -0.517400 | 0.546832 | -0.946177 | 0.3581 |
| C | 19.69868 | 2.025371 | 9.725960 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.052988 | Mean dependent var | 17.84582 |
| Adjusted R-squared | -0.006200 | S.D. dependent var | 2.186981 |
| S.E. of regression | 2.193750 | Akaike info criterion | 4.513541 |
| Sum squared resid | 77.00060 | Schwarz criterion | 4.612471 |
| Log likelihood | -38.62187 | F-statistic | 0.895251 |
| Durbin-Watson stat | 0.270486 | Prob(F-statistic) | 0.358130 |

**Regression Appendix 6: Ethanol production- *Maize, Sugarcane prices 2005***

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 32

Included observations: 18 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZEP) | -2.275214 | 0.980498 | -2.320468 | 0.0348 |
| LOG(SUGARCANEP) | 0.198237 | 0.574299 | 0.345180 | 0.7348 |
| C | 28.69571 | 4.272335 | 6.716633 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.303141 | Mean dependent var | 17.84582 |
| Adjusted R-squared | 0.210226 | S.D. dependent var | 2.186981 |
| S.E. of regression | 1.943552 | Akaike info criterion | 4.317924 |
| Sum squared resid | 56.66094 | Schwarz criterion | 4.466319 |
| Log likelihood | -35.86131 | F-statistic | 3.262576 |
| Durbin-Watson stat | 0.942983 | Prob(F-statistic) | 0.066617 |

**Regression Appendix 7: Ethanol production-*Maize, Sugarcane price, 2004-2005***

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample (adjusted): 1 65

Included observations: 37 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZEP) | -2.250218 | 0.612273 | -3.675189 | 0.0008 |
| LOG(SUGARCANEP) | 0.269523 | 0.359511 | 0.749692 | 0.4586 |
| C | 28.32701 | 2.697544 | 10.50104 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.312268 | Mean dependent var | 17.80560 |
| Adjusted R-squared | 0.271813 | S.D. dependent var | 2.109002 |
| S.E. of regression | 1.799693 | Akaike info criterion | 4.090714 |
| Sum squared resid | 110.1224 | Schwarz criterion | 4.221329 |
| Log likelihood | -72.67820 | F-statistic | 7.718938 |
| Durbin-Watson stat | 0.943333 | Prob(F-statistic) | 0.001722 |

## Regression Appendix 8: Ethanol- *Maize, Sugarcane production, 2004-2006*

Dependent Variable: LOG(ETHANOL)

Method: Least Squares

Sample: 1 99

Included observations: 64

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| LOG(MAIZE) | 0.239151 | 0.063197 | 3.784192 | 0.0004 |
| LOG(SUGARCANE) | 0.277149 | 0.127071 | 2.181061 | 0.0330 |
| C | 9.610899 | 1.860958 | 5.164489 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.364887 | Mean dependent var | 17.62239 |
| Adjusted R-squared | 0.344064 | S.D. dependent var | 2.051291 |
| S.E. of regression | 1.661338 | Akaike info criterion | 3.898864 |
| Sum squared resid | 168.3626 | Schwarz criterion | 4.000062 |
| Log likelihood | -121.7637 | F-statistic | 17.52298 |
| Durbin-Watson stat | 1.218727 | Prob(F-statistic) | 0.000001 |