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The Impact of Biofuels Demand on Agricultural Commodity Prices: Evidence from U.S Corn Market[i&ii]

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Abstract

By the first half of 2008, all around the world, international agricultural commodity prices had reached their highest level on a dollar basis in the last thirty years. The biofuel production that is considered as one of the surge reasons in the agricultural commodity price has dramatically increased over the last decade. This paper analyzes the relationship between corn demand originating from bioethanol in the United States of America (USA)and corn prices between 1993: Q1 and 2011: Q2. Accordingly, the simultaneous equations system composed of corn supply, corn demand originating from bioethanol, and corn price equations is estimated through the Three-Stage Least Squares (3SLS) method. Results of the study suggest that the corn demand originating from bioethanol has an important and positive impact on the corn prices. An increase of one percent in the bio-ethanol driven corn demand causes an increase of 0.14 % in the corn prices. Thus, it can be observed that bioethanol production growth in the USA is an important fact for explaining the increase in the international corn prices.

JEL Classification: Q11, Q42, C36.

Key words: Agricultural Commodity Prices, Bio-fuels, Simultaneous Equations Systems, U.S. Corn Prices.

I. Introduction

All agricultural commodity prices have been sharply increasing since the early 2000's. IMF's index of internationally traded food commodities has increased by 130% between January 2002 and June 2008 and by 56% between January 2007 and June 2008 respectively. Between January 2005 and June 2008, maize price has almost tripled whereas wheat price has increased by 127% and rice price by 170%. The increase in grain prices was followed by considerable increases in fats and oil prices in mid-2006. Palm oil prices increased by 200% between January 2005 and June 2008 whereas soybean oil prices raised up 192% and other vegetable oils prices increased in a similar way. During the same period, sugar, citrus, bananas, and meats prices have also increased by 48% (Mitchell, 2008).

The slowdown in the economies all around the world stemming from the global crisis in the second half of 2008 also reflected in the agricultural commodity prices. Agricultural commodity prices trended downward until the mid-2010 mainly due to the effects of the financial crisis. However, prices began to rebound from the second half of 2010 and rose to record levels in the first three months of 2011. Adverse weather conditions experienced in producing countries and the resulting historically low stock levels played a key role in the increase in agricultural commodity prices in the second half of 2010. The FAO Food Price Index, which averaged 200 points in 2008, showed a decline in March 2012 and averaged at 216 points compared to March 2011, which averaged at 232.

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Whereas the FAO Cereal Price averaged 238 points in 2008, it was recorded at average 265 points in 2011 April and 227 points in March 2012. The Oils/Fats Index, which averaged 227 points in 2008, was recorded at 262 points as of March 201 and at 245 as of March 2012 respectively. On the other hand, the FAO Sugar Price Index, which averaged 182 points in 2008, rose to 373 points as of March 2011 and was recorded at 342 points as of March 2012 (FAO, 2012). Although prices bounced back in the second half of 2011, they remain too high compared to the last decade's averages.

According to the classification introduced by the United Nations, Economic Commission of Africa (UNECA) developments affecting agricultural commodity prices vary on a large scale in the short, medium, and long run. In the short run, on the supply side, adverse weather conditions and increase in input costs adversely affect agricultural production. Concerning the demand side, demand originating from bio-fuel and increases in the Chinese and Indian food demand play a decisive role. Furthermore, foreign trade policies of different countries and financial investments in food commodity markets affect in the short run the prices of agricultural products. Concerning the medium-term, it is expected demand is originating from bio-fuel and changes in food demand in developing countries will be decisive. Having to do with long term, it is placed great emphasis on the fact that the impacts of climate change, in particular in tropical and hot regions, limited availability of water sources and outbreak and prevalence of new plant diseases will adversely affect agricultural commodities production. Accordingly, it is expected that agricultural production will decrease by 9-22% until 2080. In particular, it is estimated that cereals and maize production will decline by 30% in Africa and by 10% South Asia from their current levels until 2030 (UNECA, 2008). The fluctuations in prices of wheat and rice can be explained by relating them to changes in the supply side whereas demand changes can explain the developments in prices of maize and cooking fats and oils based on biofuel (Baffes and Haniotis, 2010).

Price increases experienced in the agricultural products and food items in line with those prices increases have some considerable effects in economic, social, and political terms. The price volatility and price increases in food prices have highly differentiated impacts on the behavior of economic units such as consumers and producers regarding economy and on overall direction and operation of the economy. The first impact on consumers is to put stress on their budgets allocated on nutrition because the agricultural commodity price surges, as well as increased prices of agricultural inputs directly cause food prices to rise which in turn increases nutrition costs. In particular, consumers in less developed countries where they often spend 50% and even 70-80% of their income on food are more severely affected by price augmentations.

In reason of the price augmentations, consumers are forced to reduce their demand for both such foodstuffs and goods and services due to the decrease in their purchasing power (OECD, 2011). Another impact of the increase in agricultural commodity prices is on the inflation rates. A price increase in the basket of inflation including several foodstuffs contributes to the augmentation of the inflation rate in the economies of both developed and developing countries. The increase in the inflation rate triggered by rising prices in agricultural commodities is lower in developed countries where food items have a share of a ten to twenty percent in the inflation basket compared to developing countries such as Bangladesh, Haiti, Kenya, and Malawi. Food expenditure in household budgets is much higher, absorbing more than the half of the household income in these countries.

In addition to their adverse impact on goods/services inflation, rising food prices can have further indirect effects on wage inflation pressures. On the other hand, inflation targeting central bank might have to curb inflationary pressure imposed by rising food prices by increasing interest rates at the expense of investment and growth (FAO, 2009). Not to mention that the rate of the effect of food inflation on non-food inflation in developing countries is much higher than in developed countries, which in turn, makes its effects more important on the general level of prices of goods and services. For example, for every one percent increase in food prices, overall inflation increases by 0.15% in developed countries whereas it increases by 0.30% in developing countries (Walsh, 2011). In this context, according to the calculations by the IMF, the effect of rising food prices for the years between 2000 and 2006 on the CPI averaged at 26.6% worldwide whereas it averaged at 46.5% in Africa (UNECA, 2008).

The effect of rising food prices on the foreign trade comes onto the scene in net food importer developing countries. The price surge affects adversely and considerably the consumers in these countries. Price rises in all food products cause a significant decline in food variety in these countries and force consumers to shift their consumption from more expensive foods, many of which include various meat and dairy products, to cereal crops intensive nutrition.

The increase in demand for these traditional ingredients contributes to the growth of cereals imports (FAO, 2009). The increase in import volume and rising food prices impose a serious balance of payments problem on less developed countries since many less developed countries are net food importers. In 2007, the total cost of food importation of the developing countries increased by 33% compared to 2006. On the other hand, the total annual food import cost of the Low Income Food Deficit Countries (LIFDCs)[4] has nearly doubled compared to the level in 2000. LIFDC countries have been importing the cereal crops having a share of 80% in their nutrition while they have been exporting agricultural commodities such as rubber and tropical product of which price increase at a relatively lower rate. A rise of 10% that emerges in the cereal prices causes an increase of 4,5 billion dollar in the imports of the net food importer developing countries (OECD, 2008). It is indicated in the report prepared by the Food and Agriculture Organization (FAO) in 2009 that for the first time in the history, the number of undernourished people has topped one billion. This figure is estimated to drop at 925 million in 2010 with the decline emerging from the 2007-2009 economic crisis. 95% of these people live in the developing countries; 580 million in Asia, 240 millions in Sub-Saharan Africa, over 50 millions in Latin America and nearly 40 millions in the Middle East and North Africa. The fact that food prices soared again in the late 2010 and early 2011 indicate that the food price issue shall have the priority in the international arena's agenda.

In addition to the boom experienced in the agricultural commodity markets since the early 2000's many others important developments have been occurring in the world markets. With the oil prices soaring in the wake of 2002 as well as national and international legal regulations arising from environmental awareness, alternative energy resources and in particular biofuels have been moving to the center of interest all around the world. The most important and widespread biofuels from agricultural crops are oily seeds (canola, sunflower, etc.), sugary plants (sugar cane, sugar beet, maize), and starchy plants (potato, and etc.) which are either consumed as food and animal feed (Biemans *et al*, 2008).

Policies and programs initiated and attempts started by USA, Brazil, EU, China and many other countries to increase production and consumption of biofuels gained importance across the globe (IADB, 2010). Accordingly, the biofuel demand and production for transportation sector use have been increasing every day. Whereas the total volume of biofuels produced for use in vehicles in 1990 was 6 Mtoe (one million ton of oil equivalent) it raised up to 10.3 Mtoe and 24.4 Mtoe in 2000 and 2006 respectively. While the share of the biofuels in the road transport oil consumption was 1.5% in 2006, it is planned to increase this proportion up to 5% by 2030. Accordingly, it is expected that this share will rise to 28% by 2030 from 13% in 2008 for Braziland for the USA to 8% from 2% respectively (IEA, 2008).

This considerable increase in the biofuel production has various probable impacts on the agriculture industry. These impacts can be listed as follows; impacts on the threat to food security, effects on the agricultural environment, effects on farmers' income and effects on the agricultural development. Threat to food security that constitutes the heart of this paper is classified into two groups, first one is "rising threat on the food supply side to food security" due to the increasing conversion of arable land to biofuel feedstock production. Second one is "threat to food security based on the rising food prices" resulting from food demand pressure (FAO, 2008). Accordingly, in this study, a threat to food security originating from the rising food prices is analyzed as pressure on agricultural commodity prices due to the biofuel demand.

2. Literature Summary

Until recent years, much of the early literature on biofuels is examined under three topics based on the approach, namely Budget Models, Partial Equilibrium Models (Sector Models) and General Equilibrium Models (Rajagopal and Zilberman, 2007). However, starting from the late 2000's, studies adopting structural econometric models and time series models also started to get involved in the literature. These models are also called cost accounting methods because they are actually based on various cost tables and spreadsheet-style cost models. In these models, the production function is typically assumed to be fixed yielding and estimates are used to estimate the profitability of activity for a single price-taking agent, such as an individual farmer or a similar entity.

[4]As of 2012, consists of 66 countries, mainly in Africa and Asia. It includes thenet food importer countries of which per capita GNP are less than $ 1,9based on the historical ceiling used by the World Bank for 2009 (http://www.fao.org/countryprofiles/lifdc/en/)

In these models, the production cost of biofuels is calculated according to various alternative production techniques. Accordingly, the profitability of crops and their production costs are estimated based on assumptions about yield, output price, and cost of production. Hallam et al. (2001) and Gnansounou *et al*. (2005) in their studies compared and assessed several techniques used for the production of bioethanol in the USA and Northern China region respectively.

Partial equilibrium models are market models developed by various international organizations and entities using simulation techniques. In partial equilibrium models, the impact to be imposed on the agricultural sector by legal regulations and policies such as pollution taxes and standards, biofuels blending mandates and subsidies is calculated. Partial equilibrium models are classified into three main categories, namely models that analyze outcomes of the regulations regarding biofuel and bio-fuels mandates at a global level, models that analyze outcomes of the regulations regarding biofuel and bio-fuels mandates at a national level and models that analyze the impact of policies regarding carbon emissions on the agricultural sector.

In partial equilibrium models that analyze outcomes of the regulations, and biofuels mandates at a global level, the impacts of biofuel demand in some large regions on the global price of food are examined. The first of these models is the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)[5] that makes a global partial equilibrium trade analysis developed originally by the International Food Policy Research Institute (IFPRI) for projection of future demand and supply for agricultural commodities (Rajagopal and Zilberman, 2007).Another dynamic partial equilibrium model is AGLINK-COSIMO[6] model developed by OECD and FAO. Yet another model is ATPSM[7] (Agricultural Trade Policy Simulation Model) developed by UNCTAD and FAO. These models are used in Rosegrant et al. (2008) Gustafson (2002), McNew and Griffith (2005), Von Lampe (2006), Tokgöz and Elobeid (2006), Taylor et al. (2006), Elobeid et al. (2006), Baier et al. (2009), Kıymaz et al (2010).

In partial equilibrium models that analyze *outcomes of the regulations, and biofuels mandates at a national level,* the impacts of regulations and biofuels mandates on a national level are simulated. According to this stochastic model developed by the Food and Agricultural Policy Research Institute (FAPRI), which is based on the simulation of the USA agriculture sector, additional ethanol capacity results in an increase in maize prices but reduced prices for ethanol, maize by-products, and soybean (Rajagopal and Zilberman, 2007). The Policy Analysis System (POLYSYS) is another partial equilibrium model through which the USA agriculture sector is simulated. The model simulates and gives predictions for the reflections and impacts on the sector of the changes in the supply, demand, prices, government program participation and payments and policies and source allocation for agriculture and livestock market (Walsh et al, 2003).

In models that analyze the impact of policies regarding carbon emissions on the agriculture sector is the Forest and Agricultural Sector Optimization Model (FASOM) which is a dynamic, nonlinear programming model of the forest and agricultural sectors in the United States. The Model forms new market equilibrium for each carbon price level calculates agricultural commodity prices, regionally specific production, input use and welfare levels and environmental impacts (Rajagopal and Zilberman, 2007). Schneider and McCarl (2003) as a result of their study concluded that maize-based bioethanol has no significant impact on carbon emission when carbon prices (equivalent to 1 ton/carbon) fall below forty dollars in the USA.

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[5]The IMPACT model is a representation of a competitive world agricultural market for 30 crop and livestock commodities, including cereals, soybeans, cotton, roots and tubers, meats, milk, eggs, oils, fruits/vegetables, sugar/sweeteners and etc. It is specified as a set of 115 countries and regions within each of which supply, demand, and prices for agricultural commodities are determined(http://www.ifpri.org/book-751/ourwork/program/impact-model).

[6]AGLINK-COSIMO is a recursive-dynamic, partial equilibrium, supply demand model of world agriculture, developed by the OECD Secretariat on the basis of existing country models. Collaborative discussions between the OECD Secretariat and the Commodities and Trade Division of the FAO (Food and Agricultural Organization), starting in 2004, resulted in a more detailed representation of developing countries and regions within the FAO's COSIMO. It covers 39 agricultural primary and processed commodities and 52 countries and regions.(http://agrilife.jrc.ec.europa.eu/AGLINK.htm).

[7]The model that was jointly developed by UNCTAD and FAO covers 175 countries and 36 agricultural commodities. ATPSM is a deterministic, static, partial equilibrium model. It analyses the effects of trade policy changes on supply and demand using a system of simultaneous equations that are characterized by a number of data and behavioral relationships designed to simulate the real world (http://192.91.247.38/tab/ATPSMabout.asp).

General Equilibrium Models assess the impacts of biofuel on the overall economy using a modeling framework that accounts for all the interactions and feedback mechanisms between biofuel markets and other markets. This method of analysis enabling the assessment of such impacts is called Computable General Equilibrium (CGE) model. CGE models are divided into two categories, namely models that analyze the impact of biofuel and carbon targets on the national economies, and models that focus on international trade. Dixon *et al.* (2007), McDonald *et al*. (2006), Reilly and Paltsev (2007)used general equilibrium models and analyzed the impacts to be imposed on agricultural commodity prices and arable lands if targeted blending mandates are met in the United States and EU countries within the framework of the biofuel directive.

Computable Equilibrium models that focus on international trade focus on and analyze the impacts of trade liberalization in agriculture and its impacts on the production and prices of agricultural commodities. Eloboid and Tokgöz (2006) simulate the impact of the removal of trade tariffs and federal tax credits on production, consumption and trade for ethanol in the United States and similarly Banse *et al.* (2007), Tokgöz (2009) in their studies, using the CGE models, simulate the impact of the EU biofuels directive for trade in the EU.

Among the studies using structural econometric models, Fortenbery and Park (2007) analyzed the US corn market using the method of the simultaneous equations system. In the study, the impact of bioethanol production growth on corn prices is analyzed through a system composed of corn supply, corn demand (animal feed, export, food-beverages and industrial demand) and corn price equations. As a result of the study, in which Three-Stage Least Squares (3SLS) Method is used, it was concluded that a 100% increase in bioethanol production will make corn prices rise by 16%. Monteiro (2009) in his study examined the interaction between the land allocated for ethanol production and food prices in a two-good (food and ethanol), one input (land) theoretical model. The study focused on the period from 1980 to 2007, and an empirical evaluation is performed for Brazil using regression analysis method. Based on the outcomes of the study, it is concluded that the increase in the productivity of bio-ethanol production has an increasing impact on food prices. In addition to the preceding, it is highlighted that an increase in the land allocated for sugarcane for bioethanol production in Brazil causes food prices to increase. Applanaidu *et al*. (2010) in their study analyzed the impact of biodiesel production on Malaysian palm oil sector by using econometric method and simulation techniques together. As a consequence of the study, it is concluded that the expansion in the biodiesel market will have an impact on Malaysian palm oil stocks, and its prices and production. In this regard, it is highlighted that rising palm oil prices will decrease the Malaysian industry's competitiveness in export markets.

Thompson *et al*. (2009) through a structural simulation model examine empirically how shocks in the corn and the oil markets affect the price and the use of the ethanol in the wake of the enactment of the Act that stipulates the use of ethanol in USA. In the study, the authors pointed out that ethanol consumer prices became more sensible to corn prices and became less sensible to gasoline prices. Vasconcellos *et al*. (2011) use structural simultaneous equation models to analyze the Brazilian bioethanol market and the effect of the increase in bio-ethanol production on agricultural commodity prices. In the study, it is stated that the effect of the bio-ethanol production growth in the international prices of sugar and other commodities is negligible in Brazil. The authors further concluded that the increase in bio-ethanol production was not solely the result of the incorporation of new farming areas but rather a consequence of the efficient bio-ethanol production methods. Likewise, the palm oil in Brazil does not have a boosting but on the contrary reducing theeffect on the agricultural commodity prices.

The literature on time-series models has been reviewed and summarized by Serra and Zilberman (2013). In the literature summary, it is highlighted that the majority of studies are based on time series models and mainly analyze the propagation/ reflection impact of developments in biofuel markets on other energy types and generally on raw material prices. Additionally, it is highlighted that the prices in biofuel markets have no impact on commodity prices in the long term in Brazil and the USA whereas commodity prices affect the biofuel prices in the long term in both countries. In the case of price fluctuations, transitivity is observable in both markets in these countries.

Zhang *et al*. (2009) used co integration analysis to examine the impact of the fluctuation in ethanol production on raw material prices. The vector error corrections (VECM) and multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) models were used in the study to analyze the period from 1989 to 2007. A strong positive correlation between the ethanol, gasoline, and crude oil prices was confirmed in the study.

The results revealed the existence of a short range relationship between ethanol, gasoline and oil prices and the prices of agricultural commodities (corn and soybean) in the period 2000- 2007 due to the bounce in the ethanol production; however this relationship was not observed in the long run. Cha and Bae (2011) by the means of the structured VAR model analyzed for the US economy the dynamic role of oil price shocks on bioethanol and corn prices. The short and long term analyses were carried out in the study through which the dynamic role of oil price shocks is investigated. In the study, it is concluded that an oil price shock will have an effect in the short run on corn prices and that thus will drive down the animal feed demand as well as export demand over the short term. On the other hand, in the long run, despite the quantity adjustments related to the demand decline in animal feed and export, the impact on the corn prices can still be observed in the long term.

Nazlıoğlu *et al*. (2012) conducted casualty analysis to investigate the relationship between global oil prices and agricultural commodity prices for the period from 1986 to 2011. The study that was undertaken in two sub-periods, from 1986 to 2006 and from 2006 to 2011 suggested that no risk and thus no price transition were apparent during the period before the year 2006. When the prices of agricultural raw products were rising oil prices and agricultural raw material prices, whereas immediately after the 2006 crisis, such price transition was viewed. The authors pointed out that subsequently the effect of this transition has changed in shape and dimension in time. Trujillo-Barrera *et al*. (2012) explored the relationship between the fluctuation in forward crude oil prices and the ethanol and corn prices in the USA for the period 2006 - 2011 by using univariate TGARCH and bivariate VECM-BEKK-MGARCH models. It is suggested in the study that the observed price fluctuation in corn and ethanol affected the fluctuation in crude oil prices by 10-20%, and during the financial crisis, this impact rose to 45%. Moreover, it is stated that the effect of the transitional volatility in the corn and ethanol markets has shifted from corn to ethanol.

The study suggests that in the short run the relationship between ethanol, biodiesel, and raw materials is weak whereas it appears to be potentially stronger in the medium term. Furthermore, it is emphasized that that ethanol has a greater effect on agricultural raw materials when compared to biodiesel and after the 2007/2008 global food crisis, the relationship between the biofuel market and the agricultural raw material markets has become highly effective. Du and McPhail (2012), explored the relationship between ethanol, corn, and crude oil prices in the USA during the 2005 - 2011 period by employing the DCC-MGARCH and SVAR methods. The authors further pointed out that especially after the year 2008, the inter-relationship among ethanol, corn and gasoline prices has been strengthened, and the growing importance of ethanol as a component of the fuel supply has worked to establish a substantial relationship between ethanol and corn prices.

Wu *et al*. (2011) explored the relationship between crude oil prices and current and forward prices of maize in the USA during the 1992 - 2009 period by using univariate TGARCH and bivariate VECM-BEKK-MGARCH models. In this study, it was concluded that the percentage of ethanol/gasoline has been changed on account of the US Energy Policy Act of 2005 and from that date on the effect of the fluctuations in gasoline prices on current and forward corn prices has increased. Kristoufek *et al.* (2012) analyzed the relationship between the prices of biodiesel, ethanol and associated fuels with the agricultural commodity prices in the short to medium term by using minimal spanning trees and hierarchical trees methods. Based on this study it was suggested that in the short term the relationship between ethanol, biodiesel, and raw materials is weak whereas it appears to be potentially stronger in the medium term. Furthermore, the authors emphasized that ethanol has a greater effect on agricultural raw materials when compared to biodiesel and after the 2007/2008 global food crisis, the relationship between the biofuel market and the agricultural raw material markets has become very efficient. Du and McPhail (2012) explored the relationship between ethanol, corn and crude oil prices in the USA during the 2005 - 2011 period by employing the DCC-MGARCH and SVAR methods. The authors further pointed out that especially after the year 2008, the inter-relationship among ethanol, corn and gasoline prices has been strengthened and the growing importance of ethanol as a component of the fuel supply has worked to establish a substantial relationship between ethanol and corn prices.

Serra (2011) uses semi-parametric GARCH analysis to identify the relationship between crude oil, sugar, and ethanol prices in Brazil during the period between 2000 and 2009. The author pointed out the strong correlation between the prices fluctuations. Zhang *et al*. (2010) applied a vector error correction model (VECM) to investigate the relationship between the prices of corn, ethanol, soybeans, gasoline and oil in the United States between 1989 and 2008. As pointed out in the study, a relationship was established between energy and agricultural raw material prices in the short term however this relationship was no longer significant in the long term.

Similar results were obtained by Qui *et al*. (2012) in their studies conducted during the 1994 - 2010 period by employing the SVAR method. Mallory *et al.* (2012) in their study employing the VECM method, found a significant relationship between forward corn and ethanol prices in the United States during the 2007 - 2012 period.

3. The Data Set and Econometric Method

3.1. Data Set

In this study, the relationship between the US corn price and bio-ethanol production driven corn demand has been analyzed. In other words, an estimation of the bio-ethanol production driven demand elasticity has been tried to be calculated. In this perspective, the corn market has been analyzed through the corn supply on the US market (S_t), bio-ethanol production driven corn demand (AF_t) and the corn price (P_t^c) equations. For the analysis, a simultaneous equation involving three endogenous variables and three equations has been constituted. The data related to the variables handled in the model to be worked with are quarterly and in US dollar and cover the period between 1993:Q_1 and 2011:Q_2. Concerning the selection of the variables, the theoretical frame, and empirical literature have been taken into consideration. The data hasbeen obtained from the United States Department of Agriculture (USDA). The original monthly data have been converted into quarterly data and itslogarithms have been taken. The trimestersare defined as Q_1:September-October-November, Q_2:December-January-February, Q_3:March-April-May and Q_4:June-July-August.The graphics related to the variables are shown below. In this system that involves three simultaneous equations, three endogenous variables, nine exogenous variables, three dummy (D_1, D_2, D_3) and a trend (T_t) variables have been used in total. The variables are presented in Table 1.

Table 1: Variables used for the model

Variable	Definition	Unit	Endogenous / Exogenous
S_t	Corn supply	Million bushel*	Endogenous
AF_t	Corn demand for bioethanol	Million bushel	Endogenous
P_t^c	Corn price	Dollar / bushel	Endogenous
P_{t-1}^c	Lagged corn price	Dollar / bushel	Exogenous
R_{t-1}	Lagged interest rate for Treasury bound	Effective interest rate	Exogenous
S_{t-1}	Lagged corn supply	Million bushel	Exogenous
ETH_t	Production of bioethanol	Thousand barrel**	Exogenous
P_t^p	Oil price	Dollar / barrel	Exogenous
F_t	Corn demand for feeding	Million bushel	Exogenous
EXP_t	Corn export	Million bushel	Exogenous
FI_t	Corn demand for food and industry	Million bushel	Exogenous
P_t^s	Soybean price	Dollar / thousand tones	Exogenous

Note:*, Bushel, in English abbreviated as (bu.)is an international unit of weight in agriculture. 1 bu= 27.216 kg for wheat, soya, green pea, potato and1 bu= 25.400 kg for rye, corn, linseed and millet. **: is a US unit of measure. 1 US barrel = 117.3 liters.

3.2. Econometric Method

Economic phenomena or relationship among the variables is usually too complex to be explained by the means of a single equation. To account for this complex relationship, an econometric model has to be established as a simultaneous equations system defining all the relationships between the variables. Therefore, the relationship between agricultural commodity prices and the bioethanol demand has been analyzed in this study through a simultaneous equations system.

Generally, structured form for the simultaneous equations model is as follows (Greene, 2008):

$$\gamma_{11}y_{t1} + \gamma_{21}y_{t2} + ...+ \gamma_{M1}y_{tM} + \beta_{11}x_{t1} + ...+ \beta_{K1}x_{tK} = \varepsilon_{t1}$$

$$\gamma_{12}y_{t1} + \gamma_{22}y_{t2} + ...+ \gamma_{M2}y_{tM} + \beta_{12}x_{t1} + ...+ \beta_{K2}x_{tK} = \varepsilon_{t2}$$

$$\gamma_{1M}y_{t1} + \gamma_{2M}y_{t2} + ...+ \gamma_{M2}y_{tM} + \beta_{1M}x_{t1} + ...+ \beta_{KM}x_{tK} = \varepsilon_{tM} \quad (1)$$

There are in the model M number of equations, M number of endogenous variables ($y_1, y_2,..., y_M$), K number of exogenous variables ($x_1, x_2,..., x_M$) and M number of disturbance terms'=*1, T* means the number of observations. The matrix terms of the model can be shown as below,

$$[y_1 y_2 ..... y_M]_t \begin{bmatrix} \gamma_{11}\gamma_{12}......\gamma_{1M} \\ \gamma_{21}\gamma_{22}.....\gamma_{2M} \\ ...... \\ \gamma_{M1}\gamma_{M2}..\gamma_{MM} \end{bmatrix} + [x_1 x_2 .... x_K]_t \begin{bmatrix} \beta_{11}\beta_{12}....\beta_{1M} \\ \beta_{21}\beta_{22}...\beta_{2M} \\ ...... \\ \beta_{K1}\beta_{K2}..\beta_{KM} \end{bmatrix} = [\varepsilon_1 \varepsilon_2 .... \varepsilon_M]_t \quad (2)$$

or as follows.

$$y_t' \Gamma + x_t' B = \varepsilon_t' \quad (3)$$

Each column of the parameters is a coefficient vector of the equation, and each rank shows an identified variable. The most crucial problem for the simultaneous-equations model is the identification problem. The identification problem consists in answering the question whether the parameters of the structured form can be obtained or not through the parameters of the reduced-form equations. If the structured parameters can be estimated from the reduced form parameters, then the equation in question is identified. For having an identifiable equation, two conditions need to be satisfied. First is the order condition that is the prerequisite and secondly the rank condition that is the sufficient condition. For being free of any identification problem, the equation needs to satisfy both of these conditions (Gujarati, 2004).

3SLS method that is one of the methods for estimating the simultaneous-equations system is applied by recurring three times consecutively the method of the ordinary least squares. By this approach, all of the models parameters can be estimated simultaneously. All of the system equations can be represented as follows in the matrix approach (Greene, 2008):

$$\begin{bmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_M \end{bmatrix} = \begin{bmatrix} Z_1 & 0 & . & . & . & 0 \\ 0 & Z_2 & . & . & . & 0 \\ . & . & & . & & . \\ . & . & & . & & . \\ . & . & & . & & . \\ 0 & 0 & . & . & . & Z_M \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ . \\ . \\ . \\ \delta_M \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ . \\ \varepsilon_M \end{bmatrix} \quad (4)$$

or can be shown as below in its most general way.

$$y = Z\delta + \varepsilon$$

Here, $E[\varepsilon | X] = 0$ And $E[\varepsilon\varepsilon' | X] = \bar{\Sigma} = \Sigma \otimes \mathrm{I}$

The three-stage least-squares method is applied in three stages:

Stage 1: The reduced-form equation is estimated for each endogenous variable making part of the model, and the endogenous variable estimator is calculated.

Stage 2: In the structured equations, the endogenous variables on the right side are replaced by constituted instrumental variables ($\overline{W}$) and transformed structured equations are obtained. The set of instrumental variables used for obtaining the estimator can be represented as follows.

$$\overline{W} = \hat{Z} = diag\left[X\left(X'X\right)^{-1}X'Z_1,...,X\left(X'X\right)^{-1}X'Z_M\right] = \begin{bmatrix} \hat{Z}_1 & 0 & . & . & . & 0 \\ 0 & \hat{Z}_2 & . & . & . & 0 \\ . & . & & . & & . \\ . & . & & . & & . \\ . & . & & . & & . \\ 0 & 0 & . & . & . & \hat{Z}_M \end{bmatrix} \quad (5)$$

By applying the simple least squares method to the transformed equations, the estimators of the two-stage least squares structural parameters $\left(\hat{\delta}_{2SLS}\right)$ are obtained. Then the variance-covariance values of the disturbance terms that correspond to the structured equations are estimated.

$$\hat{\sigma}_{ij} = \frac{\left(y_i - Z_i\hat{\delta}_i\right)'\left(y_j - Z_j\hat{\delta}_j\right)}{T} \quad (6)$$

Stage 3: By applying the generalized least squares method to the transformed equations, the three-stage least squares estimators of the structured parameters are calculated.

$$\hat{\delta}_{3SLS} = \left[\hat{Z}'\left(\Sigma^{-1} \otimes \mathrm{I}\right)\hat{Z}\right]^{-1}\hat{Z}'\left(\Sigma^{-1} \otimes \mathrm{I}\right)y \quad (7)$$

Then the asymptotical covariance matrix of the estimators

$$Asy.Var\left[\hat{\delta}_{3SLS}\right] = \left[\overline{Z}'\left(\Sigma^{-1} \otimes \mathrm{I}\right)\overline{Z}\right]^{-1} \quad (8)$$

is estimated.

The three-stage least squares estimators are biased but consistent. Since all the equations of the model are estimated simultaneously, the estimations of the three-stage least squares are asymptotic efficient.

3.3. The Structural Model and Specification

In the econometric regression models, the coefficients of the model through which their logarithms are taken (Log-log model) can be interpreted as the elasticity directly between the two variables (Gujarati, 2004). Therefore, all the equations in the simultaneous-equations system taking place in this study are log-linear (double log, log-linear). The general form of the model is shown below (Fortenbery and Park, 2008).

$$y_t = \alpha z_t^{\beta} x_t^{\gamma} e^{\delta D_t} e^{\varepsilon_t} \quad (9)$$

In the formula; α, β, γ and δ the estimated parameters z_t and x_t are respectively endogenous and exogenous. D_t Represents the dummy variable canceling the seasonal effect while e expresses the exponential function. By taking the logarithm of the equation,

$$Y_t = \alpha' + \beta z_t^{'} + \gamma x_t^{'} + \delta D_t + \varepsilon_t \qquad , \varepsilon_t N(0, \sigma_\varepsilon^2) \quad (10)$$

Is obtained. Furthermore, $E(z_t \varepsilon_t) \neq 0$ and $E(x_t \varepsilon_t) = 0$

In this study, there are in the simultaneous-equations system one supply, one demand and one price equations established in connection with the US corn market. Due to the object of the work, the corn demand for bioethanol purpose has been constituted as demand equation instead of the aggregate corn demand equation. The other components of the corn demand take place in the equation of the corn price. The constituted simultaneous equations system satisfies the order and rank conditions against the identification problem.

The equations related to the variables taking part in the simultaneous-equations system and expressing as well the endogenous variables are presented below.

Supply Equation:

$$S_t = \alpha_o + \alpha_1 P_{t-1}^c + \alpha_2 R_{t-1} + \alpha_3 S_{t-1} + \alpha_4 D_1 + \alpha_5 D_2 + \alpha_6 D_3 + \varepsilon_{1t} \quad (11)$$

While the sign of the coefficient α_2 is expected to be, negative α_1 and α_3 are supposed to have a positive sign. The supply equation is constituted of one endogenous (S_t) and seven exogenous $(P_{t-1}^c, R_{t-1}, S_{t-1}, D_1, D_2, D_3)$ variables.

Equation of corn demand for ethanol purpose:

$$AF_t = \delta_o + \delta_1 P_t^c + \delta_2 S_{t-1} + \delta_3 ETH_t + \delta_4 T_t + \delta_5 P_t^p + \delta_6 D_1 + \delta_7 D_2 + \delta_8 D_3 + \varepsilon_{21t} \quad (12)$$

While δ_2, δ_3 and δ_5 are expected to have a positive sign, δ_1 is expected to have a negative sign. The demand equation for bioethanol production purpose is constituted of two endogenous (AF_t, P_t) and seven exogenous $(S_{t-1}, ETH_t, T_t, P_t^p, D_1, D_2, D_3)$ variables.

Price Equation:

$$P_t^c = \zeta_o + \zeta_1 S_t + \zeta_2 F_t + \zeta_3 EXP_t + \zeta_4 AF_t + \zeta_5 FI_t + \zeta_6 P_{t-1}^c + \zeta_7 P_t^s + \zeta_8 D_1 + \zeta_9 D_2 + \zeta_{10} D_3 + \varepsilon_{3t} \quad (13)$$

While the sign of ζ_1 among the coefficients of the equation is expected to be negative, the signs of $\zeta_2, \zeta_3, \zeta_4, \zeta_5, \zeta_6, \zeta_7$ are expected to be positive. In the corn price equation, three endogenous (S_t, AF_t, P_t), eight exogenous $(F_t, EXP_t, FI_t P_{t-1}^c, P_t^s, D_1, D_2, D_3)$ variables are included.

4. Results of the Analysis

In the model of simultaneous equations system constituted for this study, the supply equation that is to a large extent determined by exogenous factors such as weather conditions is estimated through the method of the Least Squares (LS) whereas the two other equations are estimated by the three-stage least squares (3SLS). The model's estimation results are shown below.

Table 2: Estimation Results of the Regression

(a) Corn supply equation

Variable	Coefficient	(St. E.)	Value z
Constant	3.013656	(0.623995)*	4.83
P^c_{t-1}	-0.0288171	(0.0435646)	-0.66
R_{t-1}	-0.0158556	(0.0132671)	-1.20
S_{t-1}	0.7888808	(0.0745332)*	10.58
D_1	-1.326348	(0.0973223)*	-13.63
D_2	-1.448912	(0.0759646)*	-19.07
D_3	-1.671216	(0.0525667)*	-31.79
RMSE	0.10224*0.10224*		
R^2	0.9625		

Note: RMSE: Root Mean Square Error. *:1%, **5:%, ***:10% means that this significance level is ensured.

In the supply equation of the obtained simultaneous model (Table 2-a), the supply quantity variable of the previous period proved to be statistically significant whereas the lag corn price and lag interest rate variables proved to be insignificant. Meanwhile, the signs of the coefficients covered the expectations except for the price variable. The variable that affects to a large degree the corn supply is the lag corn supply. The degree of influence of the other variables is too little.

In the corn demand equation for the bio-ethanol purpose (Table 2-b) on the other hand, the corn price, bioethanol production amount, and oil price proved to be statistically significant while the supply amount of the previous period proved to be insignificant. Once again, the signs of all the variable's coefficients turned out to be as expected except for the price variable. In this equation, the influence degree of the oil prices over bioethanol driven corn demand is spectacular.

(b) Equation of the corn demand for biofuel purpose

Variable	Coefficient	(St.E.)	z value
Constant	-2.853667	(1.297235)**	-2.20
P^c_t	0.0402279	(0.0724948)*	5.55
ETH_t	0.5186559	(0.0821933)*	6.31
P^p_t	0.2748466	(0.0758338)*	3.62
S_{t-1}	0.2786552	(0.1815498)	1.53
T_t	0.0088239	(0.0035789)**	2.47
D_1	-0.2826503	(0.2380547)	-1.19
D_2	-0.2470233	(0.1799981)	-1.37
D_3	-0.1797048	(0.112877)	-1.59
RMSE	0.1631688*		
R^2	0.9655		

Note: RMSE: Root Mean Square Error. *:1%, **:5%, ***:10% means that this significance level is ensured.

In the corn price equation (Table 2-c) the supply amount, exports, bio-ethanol driven demand, food and industrial demand, the lag corn price, and the soya price that is the substitute good variables proved to be statistically significant whereas the animal feed demand variable proved to be insignificant.

The coefficient's signs of the exports, bio-ethanol driven demand, lag corn price and soya price variables as expected theoretically proved to be positive whereas the signs of the animal feed demand, food, and demand for industrial purpose variable's signs, although supposed to be positive, proved to be negative. Contrary to expectations, the sign of the supply variable proved to be negative. According to the results of the estimated model, the variables getting an influence on the corn price are respectively the demand for food and industrial purpose, previous period corn price, supply amount, the price of the soya that is the substitute good, export quantity, animal feed demand and demand for the bio-ethanol purpose.

(c) Corn price equation

Variable	Coefficient	(St.E.)	z value
Sabit	5.266642	(1.994602)*	2.64
S_t	-0.3885033	(0.1645536)**	-2.36
F_t	-0.1508218	(0.1061879)	-1.42
EXP_t	0.1890394	(0.0742139)**	2.55
AF_t	0.1451872	(0.0471999)*	3.08
FI_t	-0.6159988	(0.2825912)**	-2.18
P^c_{t-1}	0.5757489	(0.0678758)*	8.48
P^s_t	0.274696	(0.0808422)*	3.40
D_1	-0.1189998	(0.0672186)***	-1.77
D_2	-0.2342011	(0.1274178)***	-1.84
D_3	-0.5813418	(0.2018333)*	-2.88
RMSE	0.1101706*		
R^2	0.9146		

*Note***:** RMSE: Root Mean Square Error. *:1%, **:5%, ***:10% means that this significance level is ensured.

Conclusion

The relationship between the bio-ethanol driven corn demand amount variable and the corn price variable that are directly related to the subject of the study, proved to be significant for the analyzed period and the coefficient sign proved to be positive as expected theoretically. In the constituted model, the bio-ethanol driven corn demand coefficient was calculated as 0.14. This means that an increase of one percent in the bio-ethanol driven corn demand causes an increase of 0.14 %in the corn prices. In other words, when the bioethanol driven demand doubles then the corn prices increase by 14%.

The differences between this work and other similar econometric studies are the time interval that is analyzed and the used variables. In the previous works, the bio-ethanol driven corn demand was not constituted directly, instead the bioethanol driven demand was incorporated in the industrial driven corn demand. While in this study, the direct use of bio-ethanol driven corn demand made possible the reach of some clearer information. Another point that distinguishes this work from the others is that in the constituted model, bio-ethanol production driven corn demand was established as a function of the oil prices. In the model that was constituted accordingly, it was determined that the oil price is a variable statistically significant and highly influential over bio-ethanol driven corn demand. Namely, an increase of 1% in the oil price affects at the rate of 0.27% the ethanol driven corn demand. Generally in the model constituted in this study, results in parallel with the results obtained through the other works discussing the US bioethanol market.

It is one of the objectives in the short run for many states to increase by the double or more the production amount in the bio-ethanol sector that has a very high potential of development. In this regard, it is clearly seen that the bio-ethanol of which the production amount increases rapidly in many countries, especially in the United States, shall constitute an important element of pressure on the global corn prices.

Furthermore, when it is remembered that a rise of 10% emerging in the cereal prices induced an increase of 4.5 billion dollar in the imports of the net food importer developing countries, the impact of corn demand increase originating from bioethanol makes more sense.

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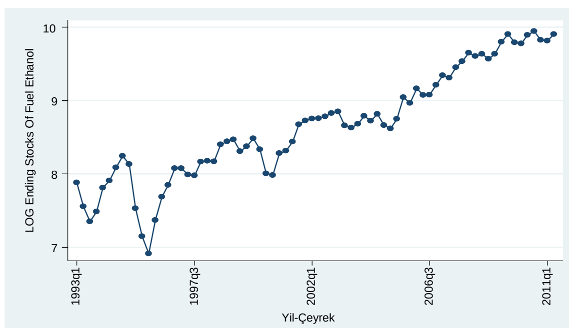
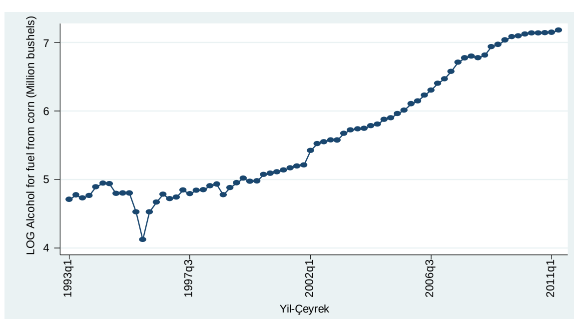
APPENDIX: The Graphs of Variables

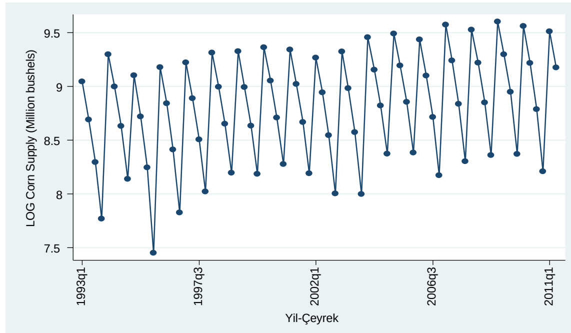
Graph 1: The Amounth of Bioethanol Stock



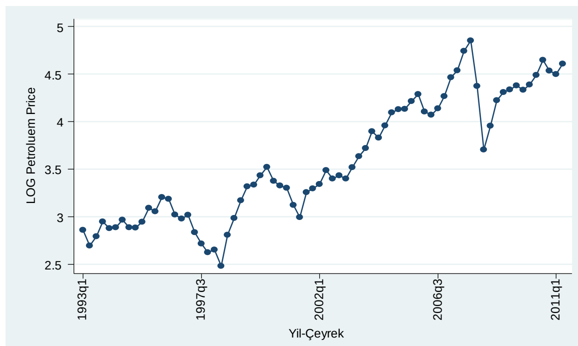
Graph 2: Corn Demand for Bioethanol



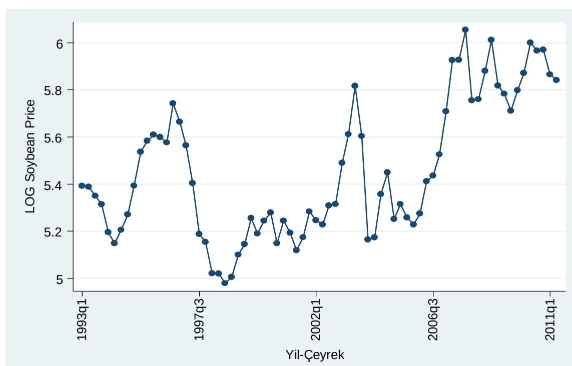
Graph 3: Corn Supply



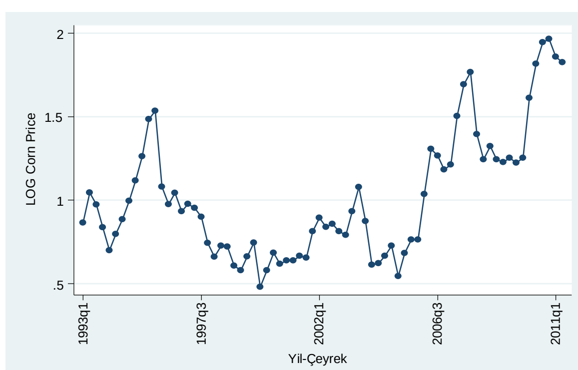
Graph 4: Oil Price



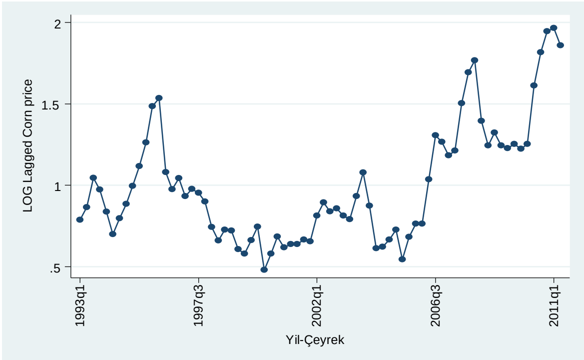
Graph 5: Soybean Price



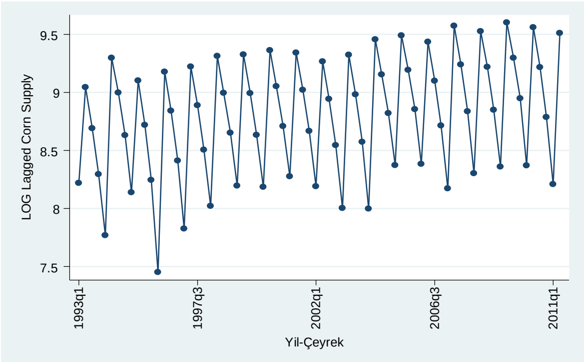
Graph 6: Corn Price



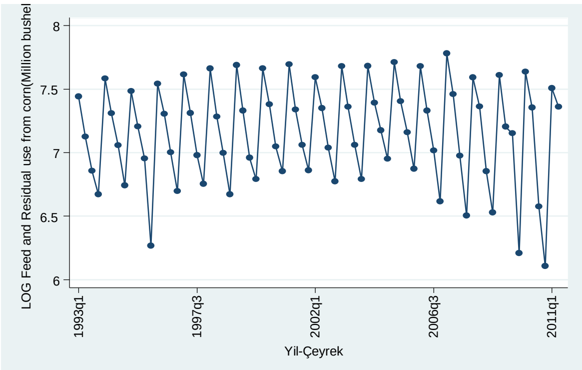
Graph 7: Lagged Corn Price



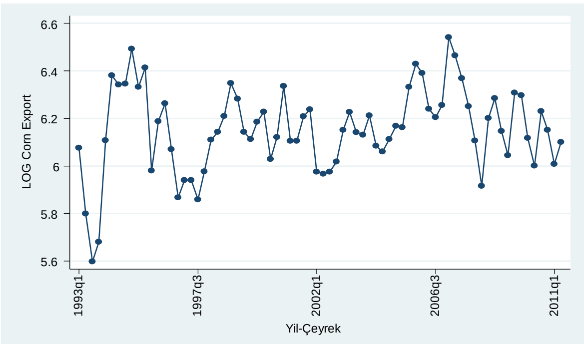
Graph 8: Lagged Corn Supply



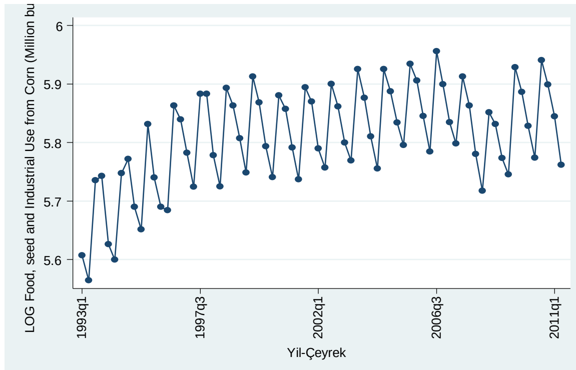
Graph 9: Corn Demand for Feeding



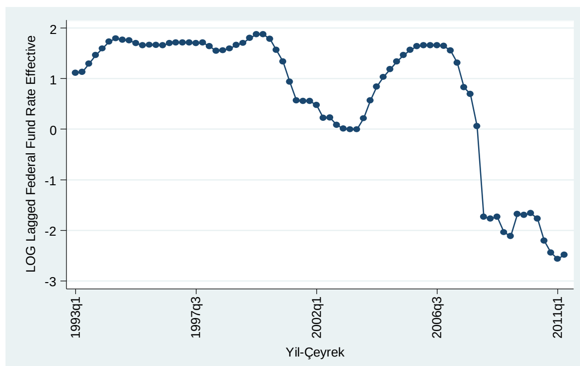
Graph 10: Corn Export



Graph 11: Corn Demand for Food and Industry



Graph 12: Lagged Interest rate for Treasury Bound



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[i] This study is derived from the PhD Thesis entitled "The Relationship between Agricultural Commodity Prices and Biofuel Demand" defended and accepted at Istanbul University Social Sciences Institute in July, 2012.

[ii] This study has presented at 17th EBES Conference-Venice as a power point presentation, the full text has not published anywhere else.