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Is Ethanol a Potential Solution to Reducing U.S. Foreign Oil Dependence?

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BY

Jasmina N. Patel

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Abstract

In this study, we estimated the impact of increasing ethanol production on net imports of crude oil in the United States. We also examined whether factors such as corn production, population, gross fixed capital formation and the Energy Policy Act of 2005 contributed to an increase in ethanol production. Using time series data from 1981 to 2012, the results of multiple regression models showed that ethanol production was a significant variable and had an inverse relation to net imports of crude oil. Our study also showed that the implementation of the 2005 Act and an increase in corn production contributed to increased ethanol production. Finally, we concluded that corn-based ethanol could be a path to reducing foreign oil dependence. Thus, we recommend that policymakers continue to subsidize the ethanol industry and also educate consumers about the benefits of using ethanol.

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1. Introduction

Energy independence is an overarching goal of many countries in the developed world, including the United States. We consider data from the Energy Information Administration[1] (EIA) from 1981 to 2012, and the trend of an increasing reliance on foreign oil by the United States for almost two-thirds of this time period has raised several concerns among stakeholders and policymakers. Although there has been a recent gradual decline in net imports of crude oil over the last few years[2], there are still concerns about possible economic shocks which may result in a reversal of this trend. The implications of this could be grave; it could threaten the country's national security, contribute to climate change, dampen economic growth, and strain international relations. Most of these imports originated from countries in the Western Hemisphere including Canada, Venezuela, and Mexico. Other major exporters of oil to the United States are Saudi Arabia and Russia. [3]

Petroleum, also known as Crude oil, is extracted directly from the ground and has several uses particularly in production and industry. It serves as a source of feedstock for the petro-chemical industry, fuel for rail and air transportation in the form of gasoline, as well as fuel inputs for the generation of heating and electricity. In addition, tar, a residual of the petroleum extraction process, is used extensively for road construction. According to EIA, gasoline production increased by 40 percent from 2,336,182 thousand barrels (TB) per day in 1981 to 3,249,605 TB per day in 2012. Gasoline consumption has also increased by approximately 25 percent during a similar time frame. The top five gasoline

[1] The U.S. Energy Information Administration (EIA) is a statistics and analysis organization which collects, analyzes, and disseminates independent and objective energy information for policymaking decisions.
[2] Trends in US net imports of crude oil between 1981 and 2012 from EIA are shown in Figure 1 in the Appendix.
[3] Percentage of oil exported by countries to United States (See Table 3 in the Appendix).

consuming states are Texas, California, Florida, New York, and Pennsylvania. Petroleum is a non-renewable resource, thus its limited supply along with the sharply rising demand for the commodity creates market conditions conducive to rising product prices. On the consumer side, this has a direct negative effect on savings (Stiglitz, 2008). With this relatively limited supply of oil, the United States is being forced to identify and assess domestic alternative energy sources.

Another major concern regarding the increasing use of fossil fuels is the fact that it imposes several negative externalities, with particular impact on the environment. The release of carbon dioxide, an important greenhouse gas, resulting from the burning of fossil fuel has been warming the earth's surface to excessively high temperatures (Lundgren, 2008). According to the Renewable Fuel Association[4], carbon dioxide emissions can be reduced by 30 to 50 percent by using ethanol instead of gasoline.

This disturbing trend has lead policymakers to revisit its current patterns of energy use. Two broad approaches are being examined. We either need to find a way to reduce fossil fuel consumption or we need to find alternative energy sources.

Seeking alternative sources of energy is not new to the United States. In the early 1900s, energy sources were derived from agriculture. In fact, in 1908, Henry Ford used agriculture-based fuel (ethanol[5]) in his original engines[6]. However, due to the low cost of fossil fuels, ethanol did not become popular from that time period up until recent day.

[4] The Renewable Fuel Association (RFA) is a vocal advocate for the use of Ethanol and has been around since 1981. Additional information including the claim regarding ethanol use and the environment can be found at http://www.ethanolrfa.org/pages/ethanol-facts-environment

[5] Ethanol fuels are also referred to as alcohol fuels because of its chemical makeup of Ethyl and Alcohol.

[6] A detailed description of the ethanol production process is provided in Figure 4 in the Appendix.

Currently, ethanol is mainly produced from corn in United States[7] (Goettemoeller et al., 2007 and Renewable Fuel Association, 2010) The US Domestic production capacity of Ethanol increased from 900 million gallons to 1.63 billion gallons between 1990 and 2000, and further to 13.5 billion gallons in 2010 (Renewable Fuel Association 2006, 2010). As of 2012, Iowa, Nebraska, Illinois, Minnesota, and Indiana were the largest domestic producers of ethanol[8]. The United States and Brazil[9] were jointly responsible for about 77 percent global ethanol production between 2005 and 2007 (OECD/FAO, 2008) and 87.1 percent in the year 2010 (Lichts, 2011 and World Bank Report, 2008).

Government intervention with the objective of reducing fossil fuel consumption has come in the form of several Energy Policy Acts which have been passed in the last 25 years. One of the early pieces of legislation was the Clean Air Act of 1990 where gasoline producers were required to maintain a specific percentage of oxygen in their product. Another was the Energy Policy Act of 1992, which was passed to require the use of alternative fuel[10] vehicles in some private and government fleets. The refinery industry started blending Methyl tert-butyl ether (MTBE) into their products, but later discovered that MTBE was toxic and ended up contaminating ground water supplies. The government quickly sought a substitute for MTBE, and this was when the benefits of Ethanol began to resurface. Given that the overall outcome of the 1992 Act was not as productive as originally intended, the government passed another Energy Policy Act in

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[7] Trends in ethanol and corn production between 1981 and 2012 from EIA and USDA are shown in Figure 2 and 3 in the Appendix.

[8] The top 28 domestic producers of Ethanol as of 2012 can be found on Nebraska's official government website: (http://www.neo.ne.gov/statshtml/121.htm)

[9] Unlike the United States where corn is used for Ethanol production, Brazil produces most of its Ethanol from sugar. (Sperling, Daniel and Gordon (2009); World Bank (1988))

[10] Alternative fuels such as biodiesel , bio alcohol (ethanol, methanol, butanol) are materials or substances that can be used as fuel, other than conventional fuel such as fossil fuel (petroleum, coal, and natural gas)

2005. The aim of this subsequent legislation was to provide tax incentives to consumers of alternative fuel. After the introduction of the Energy Policy Act of 2005, MTBE was banned and ethanol was used as an additive to gasoline. A 10 percent ethanol blend has been mandatory in some states[11] after the Energy Policy Act in 2005 was put in place.

According to the EIA, upon the passage of the 2005 Act, US foreign oil imports as a share of total demand have declined from 60.3 percent in 2005 to 49.3 percent in 2010 and further to 40 percent in 2012[12]. In addition, gasoline consumption started decreasing after 2007 and stood at 3,185,312 TB per day in 2012. Several studies have been conducted on this subject. Vedenov et al. (2006) found that switching to ethanol is an economically sound decision as long as it does not affect vehicle efficiency. On the other hand, Tatum et al. (2010) concluded that it is not sustainable to use ethanol as substitute for gasoline and should not be expected in the future. The debate about increasing corn production as the main input for ethanol production is ongoing.

Although several benefits have been cited for a transition from gasoline to ethanol, there are also some concerns associated with this move, particularly as it relates to the negative spillover effects into related industries. Some of the benefits of ethanol as an alternative fuel are its renewable, biodegradable, and environmentally-friendly properties, ease of availability, and its potential to be a path to foreign energy independence. On the other hand, an interesting case study on the negative spillover effects of increased corn-based ethanol production was presented by Wise (2012). The study found that a 20-percent increase in corn prices due to increased ethanol production

[11] The states of Iowa , Florida , Minnesota , Hawaii , Montana , Washington , Kansas , Louisiana , Missouri , Oregon have 10% ethanol blend mandatory in gasoline fuel.
[12] A full report released in May 2011 on US foreign oil trends and related data can be found at http://www.eia.gov/oog/info/twip/twiparch/110525/twipprint.html.

transmitted to the domestic market for white corn in Mexico. Tortillas are considered a staple in Mexico, and with over half of the input costs of tortillas attributed to corn, a rise in corn prices lead to an increase in tortilla costs by 14%. In addition, since 2005, the final price of tortillas to consumers increased by 69%. Other markets which were negatively affected are the dairy and meat markets since corn is a major component in the feed used for livestock. All of these trends collectively contributed to high levels of food insecurity in Mexico.

An important research question which has arisen among decision makers, and motivates our study, is whether the policy of requiring ethanol to be used as a substitute or complement to gasoline can help the domestic economy become less dependent on fossil fuels, abate some of the environmental concerns and stabilize gasoline prices.

The rest of the paper is divided into the following sections. In Section 2, we provide a selective review of related literature on biofuels (ethanol), mainly focusing on whether they are considered substitutes or complementary fuel options, along with their benefits. We also provide some insight regarding the literature on crude oil production, its use and effects. Section 3 outlines the models used in our study. The first model seeks to determine whether there is significant correlation between the domestic production of alternative fuels and foreign oil imports, and the second model examines factors which possibly affect the production of alternative fuel such as ethanol. We present the results of the two models in Section 4, providing further insights, implications and policy recommendations. Finally, in Section 5 we conclude our study, highlighting our major findings and discussing a few limitations of our study which provide potential opportunities for further research.

2. Literature Review

The use of ethanol as a primary source of energy can be traced as far back to the start of the 20th century. In 1908, Henry Ford designed an engine which could run on gasoline as well as ethanol (DiPardo, 2007). However, engines that use purely ethanol require more units of fuel than those that run on gasoline. This is because the energy derived per unit of Ethanol is 27% lower than that of gasoline fuel. The disparity depends on the specific blend of ethanol fuel[13]. As a result, gasoline stayed more popular with consumer from that time until recent years. One of the provisions of the Energy Policy Act of 2005 was to increase the percentage of ethanol blend found in gasoline. Once this Act was put into place, several states including Iowa, Illinois, Missouri, and Montana made a 10 percent ethanol-gasoline blend mandatory. According to a 1988 World Bank Report, vehicles running on ethanol fuel produce 57 percent less carbon monoxide, 64 percent fewer hydrocarbons, 13 percent less nitrogen oxide, and no lead emissions compared to cars using gasoline. Therefore, one of the main goals of the Energy Policy Act of 2005 was to abate some of the pollution associated with gasoline consumption.

As the knowledge of the benefits of ethanol use became more widespread, Tyner (2008) examined factors responsible for the boom in production of ethanol. He cited factors such as crude oil prices, the price of corn and other distillers' grains, the market value of ethanol, plant capital and operating costs, and biofuel polices enacted at the federal level. He found that policies such as the Renewable Fuel Standard, variable and fixed subsidies to ethanol producers as well as higher subsidies for cellulose-based

[13] This data was sourced from the US Department of Energy's official website: http://www.afdc.energy.gov/fuels/ethanol_benefits.html

ethanol, do not determine the extent to which renewable fuel targets are met and the cost that the government and consumer must pay. The major finding of his study was that as long as fossil fuels remain relatively more expensive than ethanol, at a level of $100 per barrel and above, ethanol production would continue even without government subsides.

According to Vedenov et al. (2006), blending ethanol with gasoline is a sound economic decision as long as it does not result in reduced vehicle efficiency. The study made specific reference to the relatively low price volatility associated with ethanol compared to gasoline. The results revealed that a decision to switch from conventional gasoline to an ethanol blend was based on real option pricing analysis. Real option pricing is a technique used while planning for a long-term investment or for increasing the value of a product. They used data from 1989 to 2004 for their study based in three US. cities: Los Angeles, Houston, and New York. These cities are located in three of the five Petroleum Administration Defense Districts[14] (PADDS) as classified by the US EIA 2004. The authors highlighted some of the environmental benefits of adopting an ethanol blend of fuel including reaching air quality goals and reducing greenhouse gas emissions. They were unable to provide conclusive results on a cost-benefit analysis between gasoline and ethanol and postponed it to further research.

A cost-benefit analysis of using domestically produced sugar-based ethanol as a substitute for crude oil imports within the north-northeast and central south regions of Brazil was performed by Rask (1995). The author used data from 1978 to 1987 and concluded that substituting ethanol for oil imports provided benefits for the central south region of Brazil but not the north-northeast region in the early 1980s. This is due largely

[14] The US is divided into regions known as Petroleum Administrative Defense Districts (PADDS) to facilitate the study of the supply and demand patterns for oil and gas.

in part to the increased agricultural yields in the central-south region of Brazil which provides evidence of increased technical efficiency in production. Given the sugar cane industry is very labor intensive, they find that the social costs of producing ethanol (including wages) are substantially higher for the north-north east region, and thus the government had to support the production of ethanol in that region. The study revealed that the Brazilian economy had spent $US3.6 billion dollars[15] in resources in two of its northern states to support the production of ethanol.

Tatum et al. (2010) also examined the economic benefits associated with substituting ethanol for gasoline in the fuel market. In general, if a consumer pays less at the pump and producers make economic profits in the short and long run, then substituting ethanol for gasoline would be a good decision. They applied a simple demand and supply analysis for ethanol and discovered that the *mutatis mutandis* cross elasticity of the ethanol 85 blend or E-85 (which comprises 85 parts of ethanol to 15 parts of gasoline) with respect to gasoline prices does not differ from one. This means that any rise in gas prices will result in a proportional increase the price of E-85. They found that given the current consumption and production technologies, and also considering the subsidies in place for E-85 production, it is not sustainable to use ethanol as a substitute for gasoline now or in the future. The authors concluded that policy makers should consider sustainability issues before making the decision to replace fossil fuel with biofuel.

An increasing number of studies examining the potential for ethanol to be considered a viable substitute for gasoline have been emerging. Zorilla (2007) examined

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[15] This amount was based in 1987 US dollars.

the potential of substituting petroleum with sugar-based ethanol in selected countries of Latin America (Colombia, Peru, and Chile) and the Asia-Pacific region (Korea, Thailand and Malaysia). These countries were selected mainly due the fact that they are highly oil dependent. Based on data from 2001 to 2005, he concluded that Thailand and Peru have medium potential to replace crude petroleum imports with ethanol. Malaysia was found to have relatively smaller potential to do so. The results revealed further that Colombia had the highest potential to replace crude petroleum imports as it engages in much greater ethanol production, surpassing the amount of refined fuel imports. Korea and Chile were not found to have the potential to substitute ethanol as a source of energy because they do not have suitable temperatures to grow sugar cane. In the end, the author proposed a program of cooperation between Latin America and Asia Pacific on the subject of energy. He suggested further research to explore the conditions under which productive, financial, and commercial cooperation on the issues of alternative energy to gasoline can be developed.

Having surveyed the literature as it relates to the evolution of ethanol as a viable energy source and a potential substitute for gasoline, our study seeks to determine whether increasing ethanol production would contribute to a reduction in foreign-oil dependence. Marzoughi and Kennedy (2012) studied the US gasoline market through five behavioral equations comprising gasoline demand, supply, production, prices and imports. They used quarterly data on gasoline imports from 1989 to 2010 and found that increases in gasoline prices and a decline of the U.S. exchange rate lead to a reduction in gasoline imports, whereas improvements in per capita GDP had a positive impact on oil imports. The study also found that an additional billion gallons of ethanol substituted for foreign oil will reduce the price of gasoline price by as much as $0.06 per gallon.

The last study we summarize estimates the US ethanol industry's contribution to the domestic economy. Urbanchuk (2013) used an Impact Analysis for Planning (IMPLAN) model in his paper for the year 2012. IMPLAN models analyze the structure of the economy as well as the total economic impact of a policy or project. In the end, the author concluded that the ethanol industry provided a significant contribution to the economy in terms of job creation, generation of tax revenue, and displacement of imported crude oil. Urbanchuk (2013) also concluded that continued growth and expansion of the ethanol industry into new technology will enhance the industry's position as the original creator of green jobs and will enable America to make further strides toward independence from imported fossil fuels.

3. Model and Methodology

In our paper, we have two times series models. Annual data for both models is taken from sources such as the Energy Information Administration (EIA), Renewable Fuel Association (RFA), and the World Development Indicators (WDI) for the years 1981 through 2012.

Model 1

In this model, we examine the effects of total population, crude-oil refinery capacity, the U.S. exchange rate, the growth rate of gross domestic product per capita(GDPR) and ethanol production on the net imports of crude oil and petroleum products[16]. More specifically, each variable was first-differenced as indicated by Δ in the model. This was done to address stationarity concerns and to achieve data smoothing of the time series. Annual data from 1981 to 2012 for net imports of crude oil and petroleum product, refinery capacity and Ethanol production were taken from the EIA website. We used the WDI database to source data on total population and per capita GDP growth. Finally, the U.S. exchange rate was provided by the Federal Reserve Bank of St. Louis.

Before discussing each variable in detail and its relevance to our study, the first multiple times series regression model is presented in [1]:

$$\Delta NI = \alpha_0 + \alpha_1 \Delta EP + \alpha_2 \Delta PT + \alpha_3 \Delta RC + \alpha_4 \Delta P1 + \alpha_5 \Delta U_{ex} + \alpha_6 \Delta GDPR + \varepsilon \qquad [1]$$

where ,

NI	= Net imports of crude oil and petroleum products (TB/day)
EP	= Ethanol production (million gallons)
PT	= Total population
RC	= Refinery capacity (TB/day)
Pl	= Energy Independence and Security Act of 2007 (dummy variable)
Uex	= U.S Exchange Rate (trade weighted US dollar index or broad index)
GDPR	= Growth rateof gross domestic product per capita (annual)

In the above model, we use net imports of crude oil and petroleum products as our dependent variable, which is measured in terms of thousands of barrels per day. As discussed previously, the extensive use of fossil fuels is a serious concern to a country's economy and environment. Therefore, it is good idea to cut down its use particularly

[16] Time subscripts were omitted for notational simplicity as there are no lagged variables in this model.

from foreign sources because rising imports leads to increasing cash outflows which negatively affects domestic savings. Our main variable of interest is ethanol production and its impact on net imports of fossil fuels.

Ethanol production measured in millions of gallons. We refer again to the study by Zorilla (2007) which examined the potential of replacing gasoline with sugar-based ethanol for several countries in Latin America and the Asia-Pacific region. We want to examine if domestic corn-based ethanol production has a similar impact on net imports of crude oil in the U.S.

Total population is an important variable for the model because the supply of a good is partly driven by the demand from consumers. Based on the documented environmental and economic benefits to energy consumers, as well as government mandates in 2005 and later, there has been a recent shift in preferences among consumers towards biofuels. However, the majority of the time series data in our study occur before this shift, and therefore we expect that an increase in population will lead to higher demand for gasoline, which in turn increases the demand for crude oil imports.

Refinery capacity (measured in terms of thousands of barrels per day) was also included as an explanatory variable because we believe it might have a positive effect on net imports of crude oil. The intuition is that the cost of producing ethanol (i.e. brand new investments in land and capital) would be greater than that associated with the import of crude oil where there already oil refinery plant and equipment.

Our fourth variable is a dummy variable representing the Energy Independence and Security Act of 2007. For years prior to this policy, we assign a value of zero; and for the remaining years a value of one was assigned. The purpose of the 2007 Act was "*to* *move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes.*" Rahall (2007). Since a major provision of the act was to reduce foreign energy dependency, we believe it will have an inverse effect on net imports of crude oil .

According to Beck and Kamps (2009), an apreciation in the exchange rate has a significant and positive impact on imports. In our model, we are using the U.S. exchange rate in terms of the trade weighted U.S. Dollar Index, also known as the broad index. This measures the weighted average of the foreign exchange value of the US dollar against curriencies of a broad group of U.S. major trading partners[17] (i.e., the value of the U.S. dollar relative to other world currencies). Our expectation is that an appreciation of the U.S. dollar relative to foreign currencies will result in an increase in net imports.

The effect of U.S. economic growth on net imports of crude oil is also examined in our model. In the study by Zhao and Wu (2007) on the determinants of China's energy imports, found that China's strong economic growth, particularly its industrial production component, was found to be a key factor influencing China's oil imports. By extension, we seek to determine whether U.S. economic growth has a similar impact on U.S. oil imports. In our model, per capita GDP growth is measured as an annual percentage rate.

[17] Some of the major US trading partners included in the broad index are European Union, Canada, Saudi Arabia, and Russia.

Finally, variables such as import tariff rates, gasoline prices and production level could have been relevant independent variables which affect net crude oil imports; however, due to insufficient data and correlation concerns we did not include them in the model.

Model 2

In this model, we examine the effects of corn production, government policy, population growth, and physical capital investment on ethanol production. More specifically, we look at the year-to-year changes in these variables. Again, this was done to address stationarity concerns and to achieve data smoothing of the time series. Annual data from 1981 to 2012 for these variables were taken from the EIA website, WDI database, and United States Department of Agriculture (USDA). The times series regression for the second model is presented in [2]:

$$\Delta EP = \beta_0 + \beta_1 \Delta CP + \beta_2 P2 + \beta_3 \Delta pop + \beta_4 \Delta gfcf + \varepsilon \qquad [2]$$

where,

EP = Ethanol production (millions of gallons)

CP = Corn production (million of bushels)

P2 = Energy Policy Act of 2005

Pop = Population growth (annual %)

Gfcf = Gross fixed capital formation (% of GDP)

The idea behind estimating this model is to determine what key factors contribute to ethanol production. If ethanol production could potentially replace net imports in our first model, then determining the key factors contributing to ethanol production would be helpful for firms and policy makers as it relates to production or policy decisions. Studies such as Urbanchuk (2013) have shown that increased ethanol production contributes to job creation, increased incomes, and overall economic growth. Ethanol production is capital intensive and may attract foreign investment, which in turn creates additional domestic employment.

According to the U.S. Department of Energy, domestic ethanol is primarily produced from starch-based crops such as corn. Ethanol can also be produced from grass, wood, and crop residues; however, the production techniques are not as well researched or developed as those from corn. This potential increase in the demand for corn as an input for ethanol production may place upward pressure on corn prices. This would then provide economic incentives to corn farmers to increase their output. Corn production in our model is measured in millions of bushels. Ceteris paribus, we expect that an increase in corn production will lead to an increase in ethanol production and vice versa.

Another important variable of the model is the Energy Policy Act of 2005. The aim of the policy was to solve the growing energy problem by providing tax incentives and loan gurantees for energy production of various types. We expect that upon the introduction of this policy there is increased ethanol production. Therefore the policy is added as a dummy variable which takes a value of zero for the years before the policy and one otherwise.

The effects of population growth, measured as an annual percentage, are also examined in this model. Tatum et al. (2010) performed a study examining whether Americans are willing to pay a premium for ethanol over gasoline. The authors found that although the overall perception of ethanol is positive, it is not globally preferred even among the consumers with a positive willingness to pay. Further, they found that consumers who are unaware of the benefits of ethanol fuel are not willing to pay the premium. Salvo and Huse (2011) report that, holding other factors constant, older drivers, heavy commuters, or motorists expressing concerns about engine performance are significantly more inclined to select gasoline over ethanol. Based on the findings of these studies, we expect population changes and ethanol production changes to move in opposite directions.

The last variable in our second model is gross fixed capital formation measured as a percentage of GDP. It explains how much of the new value added in the economy is invested rather than consumed. It is an estimate of capital expenditure such as spending on plant and machinery, transport equipment, and software by both the public and private sector. Similar to other fuel generation, ethanol production is largely capital intensive, and therefore we expect that gross fixed capital formation will have a positive impact on ethanol production.

Variables such as the refinery capacity of ethanol could have been included in our model, but there was insufficient data available. We also thought of using the Clean Air Energy Acts of 1990 and 1992 as dummy variables, however, these policies were not as relevant to the model because they did not include specific provisions regarding ethanol blends.

Before we proceed to discuss the results of the models, we address some of the general properties and treatment of multivariate time series data. First, we examine *stationarity*, a desirable characteristic in time series data. This describes a data set without a clearly defined trend which possesses a constant variance over time and a constant autocorrelation structure over time. If the data are not stationary, then stationarity can be achieved by first-differencing the data. *Lags* could also be incorporated in time series data because one variable can influence another with a time lag. In both models, we believe that only the key variables: ethanol production and corn production have a lagged effect on the respective dependent variables[18]. Another concern when dealing with time series data is the *seasonality* effect. This is typically present in daily or monthly time series data sets. The data used in our study are aggregated U.S. annual data, and so we do not face specific seasonality concerns. Lastly, data *smoothing* is another method used to fix random variation of data. In our study, first-differencing of the data was used to achieve stationarity and smoothing.

4. Results and Discussion

A series of multiple regression models were estimated using the statistical software STATA, correcting for serial correlation between variables using Prais-Winsten tests. The results are presented below:

We then estimated two variations of Model 1 which we refer to as Model 1.1 and 1.2 to examine the effect of incorporating lags and addressing endogeneity issues. The results for Model 1are presented in Table 1 below.

[18] Although there could be some justification for lagging other variables such as population, refinery capacity, per capita GDP growth, and gross fixed capital formation, when regressions were ran, the results revealed that lagging these variables did not have a significant effect on the dependent variables.

Table 1: Regression Results of Model 1

Dependent variable: Net import of crude oil and petroleum product (ΔNI)

Independent variables		Coefficient	P-value
Ethanol production	(ΔEp)	-0.6528084	0.000***
Population Total	(ΔPT)	-0.0000628	0.766
Refinery Capacity	(ΔRC)	0.6377134	0.045**
2007 Energy Independence and Security Act	(ΔP1)	287.4499	0.612
U.S exchange rates	(ΔUex)	-19.85105	0.378
Per capita GDP growth	(ΔGDPR)	93.54452	0.027***
Adjusted R-squared = 0.5404			

* 10% significant level, ** 5% significant level, ***1% significant level

In Model 1, we differenced all the variables in order to achieve stationarity of the time series. However, the tradeoff here is that the interpretation of the results will depend more on the significance levels of the variables and the signs of the coefficients rather than their specific magnitudes. Based on the adjusted R-squared for this model, approximately 54 percent of the variation in crude oil imports was accounted for by changes in the independent variables.

In this model, the results show that the ethanol production and net imports are inversely related and significant at the 1% level, which means that an increase in ethanol production will lead to a reduction in net imports of crude oil. This suggests that, to some extent, ethanol may be used as a substitute for imported crude oil.

The coefficient on the refinery capacity variable explains that an increase in refinery capacity will lead to an increase in net imports of crude oil. The relation of refinery capacity to net imports is consistent with our initial expectations and is also significant at the 5% level.

There exists a positive relation between per capita GDP growth and net imports of crude oil at the 1% significance level. Therefore, with growth in the economy, the demand for crude oil imports rises if domestic production cannot satisfy this domestic demand for crude oil in a timely fashion. Lastly, the effect of changes in total population and the US exchange rate on net imports of oil were found to be insignificant.

In Model 1.1, we seek to determine the effect of a one-year lag of ethanol production on net imports. In addition, we eliminated the policy dummy because the significance levels and signs of the other variables were not affected when it was removed. The results are presented in the Table 1.1 below:

Table 1.1: Regression Results of Model 1.1

Dependent variable: Net imports of crude oil and petroleum product (ΔNI)

Independent variables		Coefficient	P-value
Lagged Ethanol production	(ΔEP_{t-1})	-0.6463352	0.000***
Population Total	(ΔPT)	-0.001878	0.337
Refinery Capacity	(ΔRC)	0.467854	0.198
U.S exchange rates	(Δ.Uex)	-11.92606	0.531
Per capita GDP growth	(ΔGDPR)	69.5993	0.086*
Adjusted R-squared = 0.5776			

* 10% significant level, ** 5% significant level, ***1% significant level

Consistent with the previous two models, we find that ethanol production and net imports are inversely related at the 1% significance level. Per capita GDP growth was also found to be positively related to net crude oil imports and significant at the 10% level. We note that incorporating a lag in ethanol production resulted in the refinery capacity variable being insignificant. The adjusted R^2 is 0.58 for this model.

In the previous models, we used per capital GDP growth as an explanatory variable for changes in net imports; however, in reality we recognize that net imports is a major component of a nation's GDP. Hence, there might exist an endogeneity concern in the model. We addressed this by removing the GDP variable from the model. The results of this model are shown below:

Table 1.2: Regression Results of Model 1.2

Dependent variable: Net imports of crude oil and petroleum product (ΔNI)

Independent variables		**Coefficient**	**P-value**
Lagged Ethanol production	(ΔEP_{t-1})	-0.6469263	0.000***
Population Total	(ΔPT)	-0.0001215	0.578
Refinery Capacity	(ΔRC)	0.1026831	0.775
U.S exchange rates	(ΔUex)	-19.65007	0.334
Adjusted R-squared = 0.4855			

* 10% significant level, ** 5% significant level, ***1% significant level

Our results reveal that the inverse relation between our key variable, ethanol production, to net imports remained unchanged and is significant at the 1% level. The adjusted R^2 for this model is 0.49.

Model 2

In this model, we estimate the factors that affect ethanol production. As with the first model, the data was first differenced to achieve stationarity of the time series. The results are shown below.

Table 2: Regression Results of Model 2

Dependent variable: Ethanol Production (ΔEP)

Independent variables		**Coefficient**	**P-value**
Corn production	(ΔCP)	0.0891379	0.062*
Gross fixed capital formation	(Δgfcfdollar)	$-2.09e^{-09}$	0.000***
Population growth	(Δpop)	-1395.097	0.046**
Energy policy act of 2005	(P2)	1275.61	0.000***
Adjusted R-squared = 0.8956			

* 10% significant level, ** 5% significant level, ***1% significant level

As expected, the results show that there is a positive relationship between corn production and ethanol production and it is significant at the 10% level.

The coefficient on the 2005 Energy Policy Act variable was positive, which means that after the policy was enacted, there was an increase in ethanol production. The effect of the policy was significant at the 1% level. The results suggest that the objectives of this policy were achieved as it helped to boost ethanol production, which may then reduce net imports of crude oil as per our first model.

The effect of changes in population growth on the production of ethanol was also examined. Our results are consistent with the findings of Tatum et al. (2010) which state that the population is not willing to substitute gasoline for ethanol, as well as those by Salvo and Huse (2011) who found that older motorists prefer gasoline over ethanol because of engine performance.

The model revealed an unexpected negative sign on the Gross fixed capital formation coefficient. A possible explanation for this inverse relationship with ethanol production is that physical capital used in gasoline production is not easily adaptable to producing ethanol. In addition, gasoline production has remained more popular for more than two-thirds of the period in our study as an energy source due to its efficiency and economic benefits. It is more likely that increases in capital investment were more geared towards fossil fuel production. Due to resource scarcity, if there is an increase fossil fuel capital investment, then resources will be diverted away from ethanol production. It is important to note that ethanol production has been steadily rising in recent years mainly due to government mandates requiring a 10-percent ethanol blend. Therefore, we expect an increase in the flow of capital investment to the ethanol industry in the near future.

The adjusted R^2 value indicates that about 90 percent of the variation in ethanol production is explained by the model. Given the transformed Durbin-Watson statistic is lower than 2 and higher than the upper bound, we can say there is no autocorrelation in the model.

Finally, we estimated model that incorporated a one-year lag in corn production, and the results are presented in Table 2.1.

Table 2.1: Regression Results of Model 2 .1

Dependent variable: Ethanol production (ΔEP)

Independent variables		Coefficient	P value
Lagged Corn production	(ΔCP_{t-1})	0.054851	0.277
Gross fixed capital formation	(Δgfcfdollar)	$-2.00e^{-09}$	0.001***
Population growth	(Δpop)	-1265.738	0.128
Energy policy act of 2005	(P2)	1250.594	0.000***
Adjusted R-squared = 0.8572			

* 10% significant level, ** 5% significant level, ***1% significant level

Although the R^2 in this model is over 85 percent, the results show that incorporating a one-year lag in corn production means that corn production no longer has a significant effect. We can infer that corn produced in the current year is used for ethanol production in the same year. This is consistent with the production process of many biofuels where the major feedstock is generated within the same year. Finally, the 2005 government policy remained significant at the 1% level in explaining ethanol production.

Overall, we find that our results support the initial hypotheses of the study. Ethanol production was consistently shown to be a significant factor affecting the net imports of crude oil. Increases in ethanol production resulted in a reduction in crude oil imports which may potentially provide a path to energy independence. We were also able to determine that current year corn production and government policy were significant factors impacting ethanol production in a given year.

5. Conclusion

The purpose of our study was to examine two models. The first was to determine if there exists a significant correlation between the domestic production of ethanol and foreign oil imports. The results of our study reveal that there is a negative and significant correlation between the domestic production of ethanol and crude oil imports. This provides some evidence that ethanol may be a path to reducing foreign oil dependency. A second model was estimated to examine the possible factors affecting the production of ethanol. The main finding was that current-year corn production and government policy were significant factors determining ethanol production in a given year.

Achieving energy independence, with a focus on domestic ethanol production, will provide several benefits to the US economy. Substantial financial outflows will be redirected to domestic production, which will provide more jobs, increase income, and lead to an overall higher living standard. A second benefit is the favorable impact on the environment. With the substitution of ethanol for gasoline, CO_2 emissions will most likely decline, thus reducing global warming. Energy independence can possibly weaken the market power of OPEC countries in output and pricing decisions.

Based on these results, we recommend that policy makers should continue to support domestic ethanol producers using programs such as those outlined in the Energy Policy Act of 2005. In addition, policy makers should take the initiative to increase awareness among consumers about the environmental degradation resulting from gasoline use as well as the benefits of ethanol as an alternative energy source. We recognize that consumers may not immediately switch over to alternative fuel, so policy makers can provide additional incentives to consumers as they transition towards ethanol use. We also recommend that the policy makers provide support to companies producing flexible fuel vehicles.

Having outlined the benefits associated with switching over to alternative fuels, we also acknowledge the potential disadvantages of ethanol. Large quantities of energy and land are required for ethanol production. In addition, some ethanol blends are not compatible with certain types of vehicle engines.

Although the results suggest that increasing corn supply can positively impact ethanol production, there are some concerns that arise as it relates to food security, soil fertility, and price stability of other agricultural commodities.

A major limitation of our model is the small sample size used to estimate the effects of the independent variables in our study. We were limited to the period 1981 to 2012 due to data unavailability for some of the variables in the study and the relative newness of ethanol as a fuel used in the U.S.

For future research, additional explanatory variables could be estimated to improve the robustness of the model. Another possible extension could be revisiting the second model by disaggregating the data by PADD region. For instance, the majority of corn is currently produced in the Midwest region or PADD Region No.2. This may yield some interesting findings because the regions may have unique characteristics which may impact the results.

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Appendix

Table 3: Major oil exporting countries to United States from 2005 – 2012 in thousand barrel per year

Year/Countries	Canada	Venezuela	Mexico	Saudi Arabia	Russia
2005	796219	558157	606751	560823	149681
2006	858839	517947	622408	534143	134646
2007	895976	496684	559304	541987	151074
2008	912263	435029	476366	559750	170264
2009	904914	387856	441648	366605	205525
2010	925428	360526	468830	400127	223370
2011	1020604	346989	440252	436020	227774
2012	1081385	348316	377350	497570	174683

Source : Energy Information Administration :
http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_m.htm

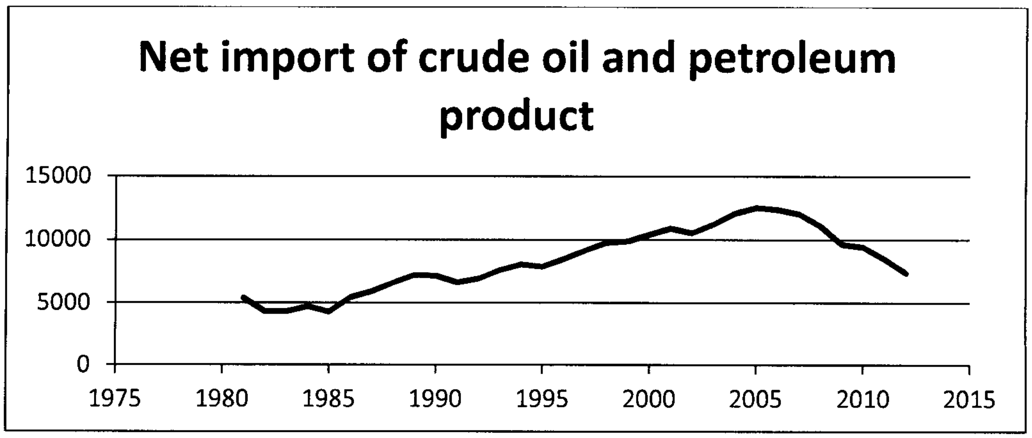

Figure 1: Trend in Net import of crude oil from year 1981 – 2012 (measured in thousand barrels per day)

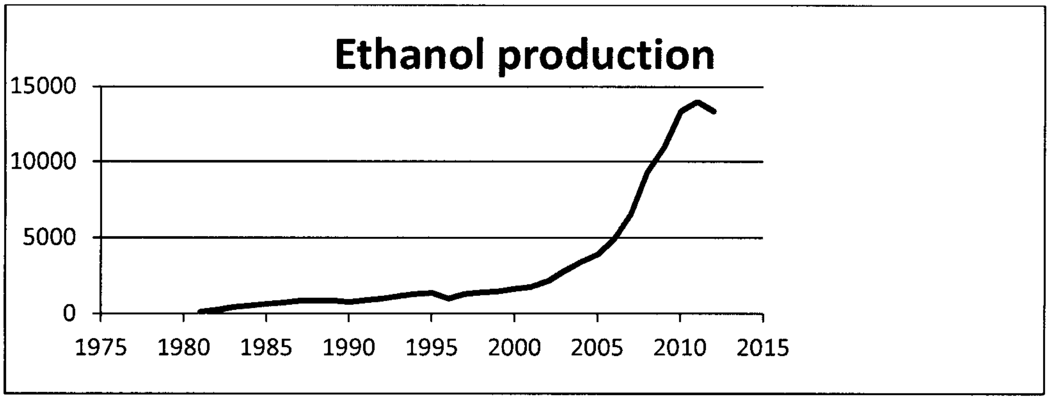

Figure 2: Trend in ethanol production from year 1981 – 2012 (measured in million gallons)

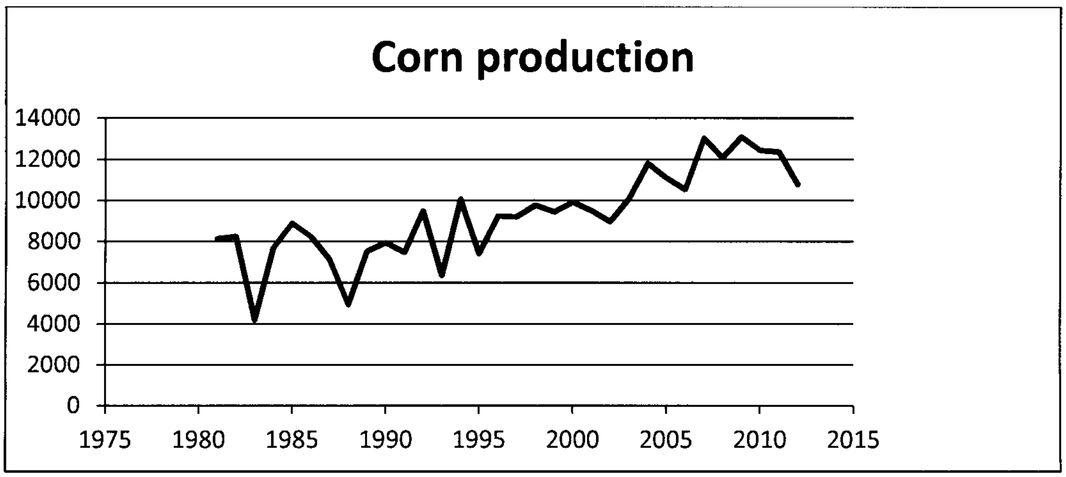

Figure 3: Trend in Corn production from year 1981- 2012 measured in million bushels.

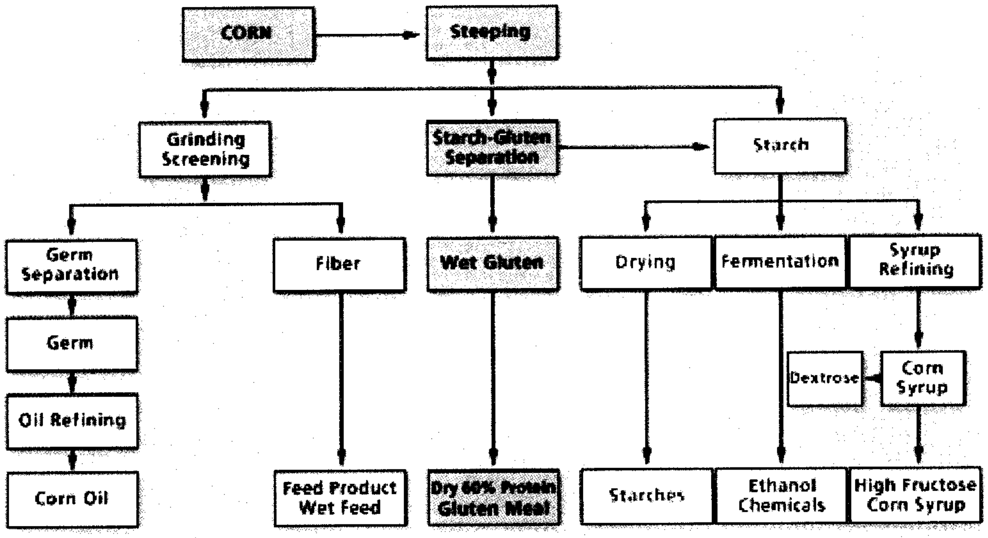

Figure 4: Ethanol production process.

Corn-based ethanol can be produced either by a dry milling or wet milling process. In the dry milling process, Corn kernels are ground into flour called meal. Water is added to this meal to create mash. In this mash, enzymes are added to convert starch to glucose. Ammonia is also added to control the pH and also serves as a nutrient to yeast. After adding Enzymes and Ammonia the mash is heated at a high temperature to reduce the bacteria level, then transformed and cooled in fermenters. Adding yeast will ferment the sugar to ethanol and carbon dioxide. The entire process takes 40 to 50 hours. Finally, ethanol is purified by the combination of distillation and molecular sieve dehydration to produced ethanol fuel. The byproduct left in this process is use to feed animals.

Now in wet milling process, corn is steeped in mixture of sulfuric acid and water for up to 2 days. The next step is to grind the mixture several times. In each grinding, they extract the byproduct. In the first grinding, they extract germ which when processed become Corn oil. It can be used for many purposes, and is sold in the market. They also extract fiber that can be fed to animals. In the second grinding, starch and gluten are separated, then some starch is used to make sugar syrup and the remainder is fermented in the same way as in the dry milling process.