DETERMINANTS FOR BIOFUEL POLICIES IN THE AMERICAS

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

July 2017

Fargo, North Dakota

North Dakota State University
Graduate School

Title

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MASTER OF SCIENCE

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ABSTRACT

The biofuels market has been increasingly important due to the benefits they provide to society by giving an alternative to fossil fuels. In the Americas, many countries are using biofuel-related policies to incentivize the production of biofuels. Different countries have different reasons to have biofuel policies, among them are variables related to country development, energy security, food security, oil price fluctuation, rural employment, and environmental issues.

With the objective of finding determinants for biofuel policies among countries of the Americas, this study conducted a logit regression with panel data using a random effect model, with information from 27 countries of the Americas for a 25-year period, available in the World Bank, FAO, and EIA.

Apart from the variables of oil reserves and rural employment, the results were consistent with our expectations. Variables related to food and energy security and country development were found to be highly significant.

ACKNOWLEDGEMENTS

Special thanks to my committee, specially to Dr. Hearne for helping me from the beginning, not only accepting me as his advisee, but also for helping me and being in touch since I was applying to the program from Chile. To Dr. Ripplinger for his guidance and great willingness to meet after hours to work on this project.

Thanks to Titan Outlet Store for making possible this experience (through the NDTO) giving me the great opportunity to be part of its working team during my course work.

Thanks to my amazing family, Tio Mario, mom and my sisters Katia and Paulina – my best examples of never giving up – for trusting and supporting me unconditionally, making me confident that no matter what, every dream is achievable and for showing me that my family will always be there to cheer me up.

To my amazing and hardworking girlfriend Patricia. Thanks flaquita for your love, support and your daily examples on how to do things right. Let´s keep learning and enjoying life together.

To the great people I met in Fargo, my friends Aaron, Marina, Daniel S., Maria, Daniel R., Emiliano, Ana, Carmen, Sergio, Federico, Luz, Carlos, Gabriela, Claudia and Jon, thanks for always reminding me what are the most important things in life – friendship, family and having fun, without that the rest doesn't make much sense. Also, thanks to Deb and Dan Maertens for all your help, mostly at the beginning of my experience in Fargo, giving me that priceless feeling of having a family being so far from home.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

CHAPTER I. INTRODUCTION

This chapter reviews the topics that should be taken into consideration when biofuels are studied. This chapter also intends to start mentioning some of the effects in society and other areas where biofuel polices exist.

Energy security (defined later) is a major economic concern worldwide, and it has a strong effect on governmental long-term policy and decision-making. Although some nations in the Americas are well-endowed with energy resources, others are not. Also, as income levels in the hemisphere have increased, environmental issues have been attracting more attention over the years because of social consciousness leading to improved stewardship of the planet and its natural resources (Huang et al., 2014). Fluctuation in oil prices, depletion of fossil fuel sources, and greenhouse gas emissions have stimulated global efforts to find sustainable and environmentally friendly alternatives to fossil fuels that can satisfy the ever-growing energy demand (Huang et al., 2012).

One potentially economic and environmentally friendly alternative to fossil fuels, especially for transportation, are biofuels. Biofuels are biological compounds from renewable sources that produce energy through combustion and can substitute for fossil fuels. For example, bioethanol (ethanol obtained by fermentation of biomass to be used as fuel) and biodiesel have the potential to partially replace gasoline and diesel, respectively (Thangavelu et al. 2016; Ramkumar and Kirubakaran, 2016). Gasoline and diesel are the two most important transportation fuels in the hemisphere (EIA, 2013). Studies suggest that bioethanol and biodiesel are environmentally friendly because their lifecycle emits less greenhouse gas (GHG) than the process to obtain fossil fuels. This is achieved mainly through GHG sequestration by growing feedstock crops (Soimakallio and Koponen, 2011; Tokunaga and Konan, 2014). Research also suggest that biofuel exhaust fumes contaminate less than fossil fuel exhaust fumes (Dale, 2007; Farrel et al., 2006). For these and other reasons, biofuels are believed to represent a sustainable alternative to fossil fuels (Brunschwig et al., 2012).

However, some researchers claim that not all the negative impacts of biofuels are always considered. Searchinger et al. (2008) show that in GHG emission calculations, the effects of changing the land use is normally not considered when the benefits of biofuels over fossil fuels are reviewed. Searchinger et al. (2008) also showed, by using a worldwide agricultural model to estimate emissions from land-use change, that using corn-based ethanol over 30 years instead of saving it almost doubles greenhouse emissions. Thus, for objective comparisons among biofuels, the efficiency of land use should be taken into consideration (Dale, 2007).

Since biofuels are a capable substitute for certain types of conventional fuels, they are being used to decelerate the depletion of fossil fuel sources. Because of this, in 2010, world production of biofuels reached 105 billion liters, an all-time high that was driven by mandates in the United States, Argentina, Brazil, Canada, China, and others (Worldwatch Institute, 2015).

A “net energy” value, which is the energy content in terms of heating value minus the fossil energy input for that fuel to be produced, is calculated to evaluate fuels. Net energy can be positive or negative (Farrel et al., 2006). Corn ethanol has a positive value and, although the difference is small, emits less GHG than fossil fuels (Lu et al., 2007). However, if coal is used in production, emissions from corn ethanol increase substantially. Biodiesel has an important positive net value and it also helps to reduce different gas emissions into the atmosphere because of the simplicity of its manufacturing process. It has also been shown that biofuels generate lower exhaust particulate emissions and GHG (such as CO, CO2, and SOx) from engine combustion (Lu et al., 2007). Ethanol can be used directly in engines that are designed for it.

However, typically, there is no modification needed to use it when blended with gasoline (Demirbas, 2011).

Besides environmental reasons, the market for biofuels has been increasingly important due to the benefits they provide society by giving an alternative to fuels obtained from petroleum (Carrareto et al., 2004; Bozbas, 2008). This market is becoming more competitive. In 2005, for instance, biofuels could not compete with petroleum-based fuels without subsidy (Hill et al., 2006). However, when petroleum prices increased after 2005, biofuels were seen not only as substitutes for fossil fuels, but also as complements in countries with biofuel policies in place (Banse et al., 2008; Demirbas, 2011); however, ethanol is most often considered a substitute for gasoline (Du and Hayes, 2009). Today it is more common to discuss competitiveness between different biofuels. For example, in the U.S., corn-based ethanol refiners have to compete with sugar cane refined ethanol from Brazil (Zhang et al., 2007).

Considering that biofuels are substitutes for fossil fuels, the idea of having them as an alternative makes more sense when extreme scenarios are considered, like the two worst oil crises experienced in major industrial countries from 1973 to 1974 that caused aggressive energy price hikes and stock market crashes (Alpanda and Peralta-Alba, 2010).

Biofuel use has increased due to the desire for alternative energy sources among other drivers, like the need to reduce GHG and to incentivize rural economic development. Biodiesel is usually produced from food grade vegetables; therefore, it represents a competition between two important sources in terms of human consumption. This often implies that it is not economically feasible to produce biodiesel from vegetable oils since they will be more expensive than normal fuels (Canakci and Sanli, 2008; Pingali, et al. 2008). Many countries in Latin America have good potential for growing biofuel crops (Cremonez et al., 2015). Brazil and Argentina, the largest countries in South America in terms of land area, are the countries taking the best advantage of that potential. Other countries in the region are starting to explore biofuel markets. Colombia, Venezuela, Costa Rica, and Guatemala are focusing on ethanol production from sugar cane. Argentina is focused on soybean fed biodiesel production (Janssen and Rutz, 2011).

More efficiency is needed to produce biofuels in South America for the countries of this region to play a role in helping to meet the increasing demand for biofuels in the world in the short and medium term (Salameh, 2003; Janssen and Rutz, 2011).

A type of biofuel that will not be part of this research but is worth a comment is advanced biofuels, also called second generation biofuels. These are biofuels produced from nonfood-sources, obtained from sub products of either farm, forestry, or biofuels related activities. Such is the case with second generation biodiesel obtained from corn oil and ethanol from lignocellulose (Menon, 2014).

Need for Study and Objectives

As mentioned, many countries are focusing on incentivizing production and use of biofuels. Countries generally do this by creating policies. The literature shows that different countries have different reasons to establish these types of policies, as countries from different income and development levels have biofuel policies in place. This is also true for countries with different levels of food and energy security, among other variables. Different theories exist to explain this, and some of them will be analyzed in this paper.

Our hypotheses for this study are: 1) a food secure nation is more likely to have biofuel policies; 2) a nation with more arable land available is more likely to have biofuel polices; 3) a developed nation is more likely to have biofuel policies; and 4) an energy secure nation is less likely to have biofuel policies.

Why is it important to identify the determinants for biofuel adoption? The answer will be useful to reformulate questions related to biofuel usage, such as its environmental impact or the effect on rural development. If it happens that the main determinant for biofuel adoption are outside the environmental side, studies on the environmental benefits of biofuels would be weighted differently, having a weaker impact. At the same time, those focused on mitigating the detrimental effects would be viewed with more importance. If the main driver is to incentivize rural development, then more researchers should focus on how to make this objective more efficient, and on how to mitigate detrimental impacts in other areas. Once clarified, knowing the determinants for biofuel policy adoption in the Americas should be used as a starting point for policy makers to boost the potential of the region based on the comparative advantage of each country.

How is this possible? Data on multiple variables related to biofuels are available for most countries in the Americas from the past several years. Econometric tools and methods, like panel data and binary variables, can be used to interpret data related to biofuels for several years and countries, and make decisions based on these tools and methods. An empirical model will be explained in Chapter IV.

From this introduction is possible to have a sense of identifying the most important factors when studying biofuels. Food and energy security are the two main concerns.

In order to achieve a better understanding, in Chapter II, provides a background in biofuels for analysis, which will set the basis for the literature review in Chapter III.

CHAPTER II. BACKROUND

Chapter II describes the territory included in this study and the main topics considered for further explanation. It will also cover what stages of biofuel usage the countries under analysis are in, along with describing what biofuels are.

The Americas, which include North, Central, South America, and the Caribbean, have a population of 1 billion people, which represents a 14% of the world´s population as of 2015. Of that population, 20% live in rural areas (World Bank, 2017). Latin America and the Caribbean, as a region, is one of the most urbanized in the world (Butera et al. 2016). The regional poverty index is difficult to measure because poverty should be measured differently for different economic levels. One indicator used to account for poverty levels is the prevalence of underweight children under five years old, which is 2.5% in Latin America and the Caribbean.

Figure 1. Map of the Americas
(Source: BREATHE https://crystalkirgiss.com/2012/11/07/a-bigger-picture-a-better-question/map-americas/).

Among youth in Latin America and the Caribbean, 21% are not working or in training; 76% of which are women, mostly because of care-giving responsibilities; and 19% work in informal jobs (OECD, 2017).

Although it has been slow, Latin America has seen significant progress on its economic development. Most the countries in the region have had a low fiscal deficit since the 1990s. Tax bases in several countries have strengthened, which has facilitated financial expansion. Economic growth averaged 5.2% from 2004 to 2008, which was the greatest growth period since 1968 to 1974 (Ocampo, 2015).

The economy in the Americas has a GDP of USD $17 trillion (USD 2010 prices), 12% of which comes from value added from the manufacturing industry (Word Bank, 2017). Agriculture has an important role in the economy in Latin America. This region also has an important role to play in the world’s food trade. With the production and export of agricultural commodities, Latin America accounted for 16% of global food and other agriculture goods between 2012 and 2014 (Duff and Padilla, 2015).

Often, the economic situation in Latin America is compared with the situation in Africa and Asia because of the known poverty conditions in these three regions. In general terms, Latin America does not have the extreme poverty levels that Africa has. This is at least in part because the policies for social development in Latin America are more inclusive than those in Africa, as will be discussed in the sections regarding food and energy security (FAO, 2006). On the other hand, economic integration in Asia has had an important and positive impact on regional poverty. In contrast, the development in Latin America has been affected by a low formal jobs creation rate, which leaves Asia, as a region, ahead of Latin America in terms of poverty management (Nissanke and Thorbecke, 2010). Üngör (2015) analyzed the difference in growth between a group of Latin American countries and East Asian countries (Korea and Taiwan). Between 1963 and 2010, Korea and Taiwan, from being poor countries, had overtaken even the more developed countries of the Latin American region, Argentina and Chile. The author concludes that the difference is due to the Asian countries’ focus on productivity in manufacturing and wholesale goods (Üngör, 2015).

With Argentina and Brazil coming out of recession and with expectation of continued growth in Mexico, Central America, and the Caribbean, the Latin American and Caribbean region is expected to grow by 1.2% in 2017 and 2.1% in 2018. The biggest constraint for growth is slow job creation (the World Bank, 2017). Argentina, Brazil, and Mexico are the countries most responsible for the recent growth seen in Latin America. The economy in this region expanded for first time in two years, as reported by “Focus Economics,” stating that the aggregated GDP increased 0.7% in the first quarter of 2017 (Focus Economics, 2017). Despite this good sign of recovery, the economy in Latin America and the Caribbean is expected to shrink by 1% before recovering in 2017 (OECD, 2017).

Latin America is polarized on behalf of economic political ideals. Some countries have democratic tendencies, others are populist and even dictatorial. This is an unavoidable handicap for countries in the region who wish to take advantage of economic growth opportunities. Those that best represent free market economies are Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, Guatemala, Mexico, Panama, Paraguay, Peru, and Uruguay; while Argentina, Bolivia, Ecuador, El Salvador, Honduras, Nicaragua, and Venezuela have adopted economic protectionism and political populism. Except for Ecuador and Nicaragua, the second group has experienced slower than average economic growth than the former (Carneiro and Brenes, 2014).

The United States is the most important producer of biofuels in the world, with production near 52 billion liters, representing 7.1 % of transportation fuels in the country as of 2012 (USDA, 2012). In 2013, the U.S. produced 50 billion liters of ethanol; Brazil, the second largest producer, contributed 24 billion liters (RFA, 2014).

Ethanol

Bioethanol, as a gasoline substitute, is a popular alternative for fossil fuels in transportation. This and other alcohol fuels are produced by fermentation of sugars that come from any sugar or starch, such as wheat, corn, sugar beets, sugar cane, and molasses. The main bioethanol production method used is enzyme digestion, which is used to obtain sugar from the natural sources to be fermented, distilled, and dried. The distillation process requires significant energy input for heat. This process generates controversy since the heat usually comes from burning unsustainable natural gas (fossil fuel). Some authors have proposed different fuels, technologies, and practices to make this process more efficient, e.g., cellulosic ethanol, wood chip for heating, and no-till agriculture (Farrell et al., 2006; Bracmort, 2015).

Ethanol is produced to substitute for gasoline as a transportation fuel; it can be mixed with gasoline at any percentage, or pure ethanol can be used in engines with the appropriate technology. However, most car engines currently used in the U.S. can run on blends up to 15% bioethanol. Ethanol has a smaller energy density than gasoline, which makes it slightly less fuel efficient than gasoline, meaning that an engine must burn more ethanol to produce the same amount of energy. Blending gasoline with ethanol does have some advantages on the technical side, one of them being that the mix has a higher octane rating than ethanol-free gasoline, allowing a higher compression ratio in the engine, thus increasing the thermal efficiency (Yücesu et al., 2007).

In 2010, the U.S. generated 49 billion liters of bioethanol, representing 57% of global output; 28 billion liters (33% of the global output and 97% of total production in South America) were produced in Brazil. The primary feedstock to produce ethanol in the United States is corn, while sugarcane is the dominant source of ethanol in Brazil (Worldwatch Institute, 2015).

The demand for ethanol in the United States expanded when MTBE (Methyl-tertiary-butyl-ether), an oxygenate used to increase gasoline octane, had to be replaced because of its detrimental effect on the environment (Zhang et al., 2007). Just like MTBE, ethanol is an oxygenate compound, but also environmentally friendly for being a renewable bio-based resource. The blend of conventional fuel with ethanol has shown significant effects on safety, engine performance and durability, and emissions (Hansen et al., 2005).

Some groups have opposed the idea of ethanol entering the market. Opponents argued that the increased ethanol demand would increase food prices, among other concerns. Also, the automobile industry has pushed back based on the potential damage that high contents of ethanol could cause to small engines since they were not designed to run with biofuels (NBC, 2010).

Biodiesel

Biodiesel is a type of biofuel usually produced from vegetable, animal, and waste oils. Mostly used feedstocks are soybean, cassava, and palm oil. It is safe, non-toxic, renewable, biodegradable, and much less contaminating than conventional diesel. It could be convenient for countries that do not have oilfields to get diesel from, to marginally decrease their dependency on fossil fuel exporting countries. The lack of reliance on imports is why some countries support the production of this type of biofuel despite its being more expensive to produce than conventional diesel (Canakci and Sanli, 2001). Global research is being conducted to reduce feedstock and production costs. To avoid using edible oil, unrefined, or waste oil and animal fat, have been used as an alternative feedstock.

Food Security

Since biofuels were considered a clean energy alternative, the competition with food production has been an issue without a clear solution, and this concern is obviously more important in food-insecure countries. The World Food Programme defines food security as the availability and adequate access at all times to sufficient, safe, and nutritious food to maintain a healthy and active life. The three key elements are, therefore, food access, availability, and utilization (World Food Programme, 2017).

Figure 2 shows that a number of countries in the tropical Americas are the most food insecure. This, of course, closely correlates with a country’s income. Nations with low income have difficulty feeding their population.

While in Latin America, poverty levels have decreased in about 50% of countries, many in tropical America are not following this trend (Schaefer, 2013). One reason why Central America is showing darker colors in Figure 1 might be found in the detrimental impact drug trafficking has on a country´s economic development (Kim, 2013; Singer, 2008).

While some authors see biofuels as a thread for food security, others, like Pingali (2008), see biofuel as an opportunity for developing countries. This author points out that beyond the impact biofuel prices could have on land usage or consumer prices, it could have a multiplier effect via rural employment, income, and asset prices. Furthermore, FAO (2017) estimates that Latin America and the Caribbean, along with Sub-Saharan Africa, have the largest available land area. This should facilitate the expansion of land-intensive biofuel crops. Thus, some countries could have the potential to take advantage of biofuel crops while others could experience a detrimental effect on food security issues due to an increase in food prices (Gallagher, 2008). In order to control food security issues, among others related to biofuels sustainability, several Latin American countries have engaged in programs to promote biofuel production and use, although some are in an early stage of development in this field (Janssen and Rutz, 2011).

Figure 2. The FAO hunger map
(Source: Hungry Map FAO, 2015).

The increase in demand for biofuel crops has a strong global impact on agriculture (Banse et al., 2008). It is known that the most controversial issue on biofuel production comes from its competition with food crops, because of the potential impact on food availability (Devadoss and Kuffel, 2010). Gallagher (2008) for instance, says in his review, ‘Literature and Arts of the Americas,” that biofuel production should be based on their capability to diminish greenhouse gas (GHG) emissions, but it is also important to consider their effect on food security. Graefe et al. (2011) concluded, that as a result of a theoretical approach on biofuel production efficiency in Costa Rica and Ecuador, the ecological impact caused by biofuels highly depends on the source used in the biofuel’s life cycle. From the last work cited, it can also be inferred that this also applies to food security, because the improvement in ecological impact, and inherently in food security, comes from using industrial waste products to produce biofuels (Greafe et al., 2011).

Latin America is far from being the most vulnerable region in the globe, as mentioned before, but the situation is worse in several countries of Africa and Asia. Latin America and the Caribbean have met international hunger goals by halving the percentage and total number of undernourished people – the target of both the Millennium Development Goals and the World Food Summit Goal (FAO, 2006). However, it is not free from being affected by the indirect effects that biofuels cause, one of the most important being an increase in food commodity prices affecting poor people directly, mainly in the long term (Gallagher, 2008; Koizumi, 2015).

Nevertheless, it must be considered that integrating the market of biofuels has a consequent increase in international trade participation (Dufey, 2007), and trade openness has a subsequent positive effect on food security. This is according to a study conducted by Dithmer and Abdulai (2017) in which they used cross country panel data to analyze the effect in trade openness in food security. The authors concluded that the beneficial effect goes directly to dietary energy supply adequacy, dietary diversity, and diet quality-related aspects of food security (Dithmer and Abdulai, 2017). Somewhat contradicting the recently cited author, it is also believed that biofuel can have a negative impact on food security. Koizumi (2015) said this is true at national, sub-national, household, and individual levels after conducting econometric analysis of price elasticity of both feedstock supply and demand using time series data in scenarios of different countries. Although, with a big influence on how polices are dictated, biofuels could also have a positive impact on food security in the long term as a result of the creation of opportunities in favor of agricultural development (Koizumi, 2015).

One of the reasons the World Food Program (WFP) gives as important to food security is gender inequality. The WFP claims that gender inequality has a close correlation with food security issues and poverty, because an estimated 60% of chronically hungry people are women and girls and 20% are children under five (WFP Gender Policy, 2009). Population has also a clear effect on food security, being a population to be fed according to a country´s economic potential, as explained by Pimentel and Giampietro (1994). Adding biofuel production and policies to the recently mentioned is believed by some authors to worsen the food security scenario. In a study using southern Asia as an example, Fischer et al. (2009) estimated that if all the announced biofuel targets are met by 2020, about 140 million additional people would be at risk of hunger, about 15 million of whom would be from Latin America. This is because of the food price increase that the demand for biofuels would create (Fischer et al., 2009).

Since countries have different natural endowments, and because biofuel production impacts them differently, the Inter-American Development Bank (IDB) developed its scorecard for sustainable biofuels after the price hikes in 2008 to support biofuel production in some Central and South American countries (Janssen and Rutz, 2011). The IDB changed its criteria of focusing in land use to focus in yields, and paying more attention to non-food biofuels crops (like jatropha and sorghum) and in second generation options like the production of ethanol from wood chips (Swaminathan et al., 2013).

Energy Security

Another important topic to consider analyzing in the biofuel market, is energy security. The IEA (International Energy Agency) defines energy security as “the uninterrupted availability of energy resources at an affordable price.” It is analyzed in three different forms: long-term energy security that considers the availability of energy to allow economic developments and environmentally sustainable needs. Short-term energy security consists of the capacity of a country´s energy system to react to sudden changes in the balance of supply and demand. Finally, the lack of energy security refers to inaccessible energy prices or physical unavailability of energy impeding economic growth and having a negative social impact (IEA, 2017).

Figure 3 shows different risk levels on energy security among countries in the Americas. It was adapted from the International Energy Security Risk Index and calculated by the US Chamber of Commerce for the top 75 energy-consuming countries in the world in 2016. In the map, green indicates a country that belongs to the quartile I of risk level (lowest risk), yellow indicates quartile II, orange means quartile III, and red is quartile IV (highest risk); countries in white are not part of the top 75 energy-consuming countries. Only two countries in the Americas were considered in a high-risk level, Paraguay and Trinidad and Tobago (US Chamber of Commerce, 2016). Paraguay is one of the countries in the Americas with more access to electricity with 98.5% according to Butera et al. (2016), and it is the country with the highest ethanol content mandate (E25%) (Lane, 2016).

The situation in energy security in different countries of the Americas varies considerably. While some countries like Chile or Paraguay cannot produce enough oil to supply their own demand, countries like Brazil, Mexico, Venezuela, and Colombia are the largest oil producers in the Latin America, with production of 2.95, 2.8, 2.7 and 1 million barrels per day, respectively, in 2014 (Carpenter, 2015). It is important to mention that Venezuela is the country with the largest proven oil reserves in the world (CIA, 2016); however, this country is not part of the first quartile (lowest risk) in the International Energy Security Risk Index and is far from being the number one oil producer (it is number 12). This is believed to be caused by mismanagement from the Venezuelan government; but also, the extra heavy crude oil from

Venezuela needs specialized refiners, making the obtaining process more expensive (Wang and Li, 2017).

Figure 3. International energy security risk index
(Source: US Chamber of Commerce http://www.energyxxi.org/international-energy-security-risk-index).

Use of Biofuels

Biofuels are used because of their capability to replace or be combined with fossil fuels to improve ignition power by increasing the octane content. Several tests have been done with different engine types, demonstrating that ethanol can improve some engine function properties. Using ethanol has been shown to significantly decrease particulate materials emitted from exhumes (Serdar et al., 2006). Among other properties that can be improved in an engine, ethanol has been shown to improve the stability, viscosity, and lubricity of the mix; regarding safety and materials compatibility, no detrimental effects have been found. However, the author indicates that in the case of ethanol-diesel blend, some modifications to the gas tank could be necessary, and more research needs to be done in respect to this matter (Hansen et al., 2005). How well the biofuels market can be developed in a certain market depends, among other factors, on the competition coming from other countries. In general, on behalf of global energy demand to 2020 and beyond, the main drivers are: (1), population growth, (2) economic growth, (3) industrialization, and (4) urbanization (Rothkopf, 2007).

Current Situation in Latin America in Biofuels

A number of Latin American countries are in an early stage of developing a market for biofuels. To take advantage of their resources and favorable framework conditions, some of them are engaged in programs to promote biofuel production and usage (Janssen and Rutz, 2011). Although South America might have the potential to produce biofuels, more technology needs to be adopted in these agricultural systems. This should not only help supply biofuels for the global demand, it is also believed that it would lead to poverty reduction by increasing income and developing more job opportunities in the region (Pingali et al., 2008).

South America has considerable potential to contribute to global energy supply because it has several renewable energy sources, such us hydropower. This potential will be an advantage when prices of fossil fuels increase because of an eventual scarcity. Ethanol and biodiesel represent most of the biofuels in South America, with Brazil and Argentina being the leading producers. Since the rest of the countries do not have legislations to provide incentives to use biofuels, many of them are trying various alternatives to meet the demand for biofuels (Cremonez et al., 2015).

The success of the incorporation of biofuel crops in these nations will also depend on some political factors (Banse et al., 2008). It is expected that more countries will put policies in place in favor of producing biofuels since their use is believed to improve environmental conditions (Silva et al., 2011). It is accepted that biofuel blending policies are indispensable to meet targets of using biofuel crops in the petroleum sector. Trade liberalization has also been beneficial by improving the efficiency of resource allocation, promoting productivity growth and stimulating employment opportunities (Pingali et al 2008).

Competition between the region's largest producers will be an important factor for the introduction of biofuels into emerging Latin American markets. In the United States, the corn-based ethanol industry is vulnerable to limit-price competition, where one company or more sells at a lower price than the marginal cost new companies would if they entered the business (to avoid competitors). In the case of ethanol, the competition was based on price against MTBE (ethanol substitute). Since MTBE is produced and sold at a lower price, ethanol had to compete without a mandate forcing its use (Zhang et al., 2007). After mandates were created, it was found that the introduction of ethanol in the market had some influence on the price of gasoline (Luchansky and Monks, 2009).

Energy security issues in Latin America are considerably better than in Africa. However, unlike Africa, in Latin America, where 24% of the urban population lives in slums, the energy security risk comes from high electricity high prices that makes it unaffordable for slum dwellers. The low efficiency of electric appliances makes the situation worse. The difference in both continents' situation could be due to different approaches used by utilities and policy makers. In Africa, slum dwellers are considered illegal, so they are not considered in the extension of basic services; while Latin America is aiming to legalize slums and provide energy service among other projects (Butera et al. 2016).

Countries with Biofuel Policies in the Americas

Out of the 27 countries considered for this paper, only 12 have biofuel policies in place, as summarized in Table 1 with data obtained from Barros, 2015; Dessureault, 2016; Gruenspecht, 2016; Joseph, 2014; Lane, 2014; La Gaceta Nro. 132 artículo 13; Sapp, 2015a; Sorda et al. 2010; and Ruiz, 2016.

Table 1. Biofuels policies in the Americas

	Mandate (Start Year)	
Country	Ethanol	Biodiesel
Argentina	E5 (2006)	B5 (2010)
Brazil	E22 (1993) E15 (2011) E25 (2013)	B5 (2010) B7 (2014)
Canada	E5 (2010)	B2 (2011)
Colombia	E8 (2010)	B8 (2010)
Costa Rica	E8 (2013)	B5 (2013)
Ecuador	-	B5 (2013)
Jamaica	E10 (2011)	-
Panama	E2 (2013) E5 (2014)	-
Paraguay	E18 (2007)	B1 (2007)
Peru	E7.8 (2010)	B2 (2009) B5 (2011)
United States	E2.78 (2005)	B* (2010)
Uruguay	-	B2 (2009)

* Policy varies upon type of biodiesel and size of blender.

Canada started an E5 policy in 2010, and some provinces (like Saskatchewan and Manitoba) have decided to exceed that percentage. A B2 policy was adopted in 2011(Dessureault, 2016).

Costa Rica's mandates of 8% ethanol and 5% for biodiesel (La Gaceta Nro. 132 artículo 13) had not been met as of 2016 (Ruiz, 2016).

In Uruguay, the B2 policy in place since 2007 was optional until 2009 when it was dictated to be obligatory (Lane, 2014).

The United States has had tax credits programs to promote usage of biofuels since 1978. To control a tax credit created in 2004 to benefit ethanol producers, an ethanol import tariff was also created. Both the tax credit and tariff were eliminated in 2012 (Sorda et al., 2010).

The United States also has renewable fuel standards (RFS) as the result of two policy acts, one from 2005 and another one that expanded the former in 2007 (RFS2) (Gruenspecht, 2016).

Biofuels Policies in Latin America

Several countries outside the United States are implementing mandates to have motor fuels mixed with biofuels. In the Americas, the U.S., Argentina, and Brazil are the most important nations in the production of biofuels. These nations also have significant mandates in place. Brazil has the highest percentage of bioethanol mixed in its gasoline, which varies between 20% and 25% depending on the size of its domestic sugar crop, sugar prices, gasoline prices, and ethanol prices (Wisner, 2013). In addition, Banse et al. (2008) demonstrated that the goals of the EU Biofuels Directive (European Commission, 2003) of increasing the amount of biofuel crops will not be met in Europe if the respective governments don't make policy intervention to stimulate the use of biofuel crops.

By 2014 there were 63 countries with mandates related to biofuels or at least targeting to have a measure to increase the use of this type of fuels, 14 of them from the Americas. In Central and South America, Argentina, Brazil, Colombia, Chile, Costa Rica, Ecuador, Mexico, Panama, Paraguay, Peru, and Uruguay have policies promoting biofuels (Lane, 2014; Lane 2013). Venezuela, with the world's largest petroleum reserves, is the only large nation in South America that does not have policy support for biofuels and it is not planning to do so.

Argentina

Argentina is one of the most important countries in South America's biofuels market. It is a leading producer of cereal grains, and thus has a comparative advantage in biofuel production. Argentina has shown a decreasing trend in the export of biodiesel. In the first trimester of 2015, exports reached only 58% of exports in the same period in 2014. In 2014, 200,000 tons of biodiesel were sold internationally from Argentina (Sapp, 2015a).

Argentina started to promote the biofuel market in 2006 with law 26,093. This law mandated: 1) mixing gasoline with 5% bioethanol, and 2) by 2010, diesel had to be mixed with 5% biodiesel. The law allowed companies that produced one of these biofuels to choose between three alternatives: 1) produce for the domestic market, taking advantage of tax incentives, 2) produce for self-consumption, also taking advantage of tax incentives, or 3) export the produced biofuel with no tax incentive.

As of 2015, biodiesel exports from Argentina for 2016 was expected to be close to 1 billion liters, which is lower than in 2014 but higher than in 2015. The main buyer for this product is the United States to generate RINs (Renewable Identification Number) under the Renewal Fuel Standard Program (RFS) (Joseph, 2015). The domestic market was also affected by an increased export tariff and lower official mandate prices (Joseph, 2014). In 2014, Argentina´s government reduced the export tariff for petroleum exportations through a national mandate (Resolución 803/2014), which dictates that when the international price of crude oil is below US$80 per barrel, the retention of the exportation will be 13%. If the price drops below US$ 75 per barrel, this retention will be 11.5%. And if the price of this good falls below UD$ 70, the export tariff will be fixed at 10% (El Patagonico, 2015). This fact should stimulate the biofuel market in the nation in addition to the 2012 mandate that requires the gasoline mix to contain between 5% and 10% bioethanol, as indicated in article number 7 of resolution 5/2012 (InfoLeg, 2012).

One of the most important factors in Argentina that affects the marketing of biofuels in this nation is the existing export tax. Argentine exporters face a tax up to 13%, along with the low fossil fuel prices. This makes the nation’s biofuel producers believe it is nearly impossible for the industry to continue operating (Sapp, 2015b).

Although Argentina produces more biodiesel than bioethanol, the production of bioethanol has increased considerably since the mandate of 2010 took effect. Bioethanol production (mainly from sugarcane) is predicted to be 720 million litters for 2015, the highest ever produced. From 2010 to 2012, all the bioethanol was produced from sugar mills but in 2012, two maize-fed ethanol plants started to operate. As of 2015, there were five grain ethanol plants working in Argentina with an annual production of 500 million liters and nine sugar mills with capacity to produce 450 million liters of ethanol per year (Joseph, 2014).

Brazil

Activity in Brazil has a big impact on the world biofuel market, since it is the second largest exporter in the world.

As previously mentioned, sustainability has become a huge issue in the biofuels area, and even more so when speaking about trends and evaluating new competitors. The government of Brazil has developed programs that have shown the feasibility of sustainable methods for renewable fuels utilization. Data show that greenhouse gas emissions reduction has been greater than 80% since ethanol use in Brazil. The government is still doing research to keep improving the sustainability of domestic biofuels (Silva et al., 2011).

Brazil is not the second larger actor in the biofuels market in the world only for its ethanol production, but also for its participation in the biodiesel market. The government programs are focused on biofuels in general, ethanol and biodiesel being the most important. These are key programs for the emerging biofuel markets, which is why they have provided Brazil leadership in the promotion of biofuels around the world (Wlkinson and Herrera, 2010).

Brazil started promoting the use of biofuels in 1930, and already in 1977 the government established a blending mandate of 4.5% ethanol into gasoline, which would increase with the years as a response to the international oil crisis in the late 1970s. When oil prices decreased in 1989, Brazil had to start investing in its own production. In the early 1990s, the minimum blend for ethanol to gasoline was 25%, but it was lowered to 18% in 2011 (Barros, 2015).
In 2009, President Da Silva announced a mandate of a 5% (B5) minimum blend of biodiesel to diesel starting in 2010 (Stattman et al., 2013).

In 2013, the government reduced the blending percentage of ethanol from 25% to 20% because of the difficulties in the ethanol supply that developed when prices of sugar increased. But the same year, it was increased back to 25% (Lane, 2013). In September 2014, the Brazilian senate voted to increase the maximum blend from the current 25% of ethanol blending mandate to 27.5% (Lane, 2014). The Brazilian government approved a rise in biodiesel blend to 7% and is planning to raise it to 10% by 2018 (Sapp, 2015c).

For the biodiesel mandate, the industry claims they have invested more than $3 billion producing this fuel so they expect the government to increase the minimum blend to 6% soon so they can sell more domestically (Lane, 2014).

Colombia

Colombia, with a production of 35 million tons of sugarcane in 2013, is one of the four most important countries for biofuel production in Latin America, the other three being Brazil, Argentina, and Mexico (Perez and Acharya, 2015). The government of Colombia formed the first biofuel policy in 2004, with tax exemptions for fuel blended with biodiesel. In 2005, the the blend percentage was set at 5% of biodiesel into diesel, but for different reasons it was not until 2008 that the mandate occurred and raised it to 8% (Corredor, 2009). In 2007, the blend in both fuels, diesel and gasoline, was increased to a minimum of 10% and 20% of biofuels beginning in January 2010. The same decree obligated the auto industry to sell flex-fuel cars from 2012 and on, ready for E-20 (20% of bioethanol blended with gasoline) and B-20 (20% of biodiesel blended with diesel) (Corredor, 2009). By 2008, Colombia had in place a mandate that requires gasoline sold in the country to be blended with 8% ethanol (E8), and as of 2014 were discussing the feasibility of increasing this percentage to 10% (Lane, 2014).

In Colombia, ethanol is primarily obtained from sugarcane, and the prices of this biofuel are fixed by the government, which bases its decisions on international sugar prices. To increase the consumption of biofuels in Colombia, bioethanol is exempt from value added taxes (VAT) as well as the revenue obtained from crops used as biofuel feedstocks (Sorda et al., 2010).

Costa Rica

Costa Rica is among the most energy secure countries, as 99% of the population have access to electricity (Butera et al., 2016). It is one of the most politically stable democracies in the region. Its agricultural investments are classified as “medium” by the FAO, which also classifies its foreign investments as “low to none” (Soto and Gómez, 2012).

Costa Rica is a beneficiary of the Caribbean Basin Initiative (CBI) launched through the Caribbean Basin Economy Recovery program (CBERA) created in 1983. The program allows ethanol produced at least 50% in *basin* countries to be imported duty free into the United States. This gives the opportunity to the CBI countries to export their own plus 50% foreign ethanol to the US, using a dehydration process in order to make transport more efficient (Elobeid and Tokgoz, 2008). The main goal of this program was to provide a loophole through which Brazil could export ethanol to the US without paying the import tariff against this biofuel (Wilkinson and Herrera, 2010).

Costa Rica is also part of the Mesoamerican Biofuels Program (Rogat et al., 2015) and it was the first country to establish a market in carbon sequestration credits. The country has important foreign investment in areas related to environmental improvements (Borras et al., 2012). Along with Colombia, Venezuela, and Guatemala, Costa Rica is working on producing ethanol from sugarcane (Janssen and Rutz, 2011); however, studies are being conducted in the country to evaluate other sources for biofuel generation with the hope to take advantage of local industries, such as biomass from banana byproducts being used for ethanol generation (Graefe et al., 2011).

Ecuador

Ecuador is on the list because of its biodiesel policy, although it is one of the lowest on the list in biofuel consumption in the transport sector, with 0.92%, and fifth in biodiesel production efficiency out of nine Latin American countries evaluated (Gómez, 2016). Ecuador is among the countries in Latin America taking initiatives to promote the biodiesel industry from palm oil and soybeans (Janssen and Rutz, 2011). Before the B5 mandate, put in place in 2013, Ecuador exported its biodiesel production, mainly obtained from palm oil, mostly to the US, Peru, and Italy. Petroecuador (a national oil company) was expecting the national demand to be 6 million metric tons because of the B5 mandate. This mandate was programmed to increase up to 10% in the near future (Lane 2014). The country is also evaluating alternatives to generate ethanol from banana industry discards. It is estimated that about 10% of the economically active population benefit from the banana industry (Graefe et al., 2011).

Ecuador is considered a country with low efficiency for bioethanol production (Gómez, 2016); however, it is looking to have an E10 blending policy by 2018 (Lane, 2014).

Jamaica

Jamaica, facilitated by the incentives from the CBI program, has an ethanol dehydration plant, which makes ethanol transport to the U.S. more efficient. This type of facility is also present in Costa Rica and El Salvador (Elobeid and Tokgoz, 2008). However, Jamaica has not produced any considerable amount of ethanol to supply its own E10 mandate, which has been in place since 2011 (Jamaica Observer, 2016). The reason for this might come from Jamaica’s role in the ethanol trade between Brazil and the US (Wilkinson and Herrera, 2010). After the ethanol import tariff was eliminated in the US, some dehydration plants closed, and currently, new projects to work with sorghum ethanol are taking place (The Gleaner, 2016).

Panama

Panama started with an E2 mandate in April 2013, and it was increased to 5% one year later with the goal of increasing it again to 7% in April 2015 and 10% in April 2016 (Lane, 2016). However, these percentages are voluntary and do not obligate consumers to buy gasoline with bioethanol. The same applies to biodiesel; and although Panama does not indicate the percentage to use, it authorizes the blend to be commercialized (Proyecto de Ley 037).

Panama was one of the countries that benefited from the CBI program (Zhang et al., 2007). However, after the ethanol import tariff in the U.S. expired, the percentage of ethanol to be blended with gasoline was increased, and more refinery plants were built. Ethanol blending increased the price of gasoline. This was controversial since the major ethanol refinery in the country was built by a company owned by the president's family (La Prensa, 2014).

Paraguay

Paraguay is the second largest sugarcane ethanol producer in Latin America, although still considered a country with a medium level of efficiency for ethanol and low efficiency for biodiesel production. It would have to increase its sugarcane production in about 47,000 tons, which is about a 1% increase, to reach the efficiency frontier. But it would have to produce 70,000,000 tons of soybeans, seven times more than its current production, to be efficient in biofuel production, (Gómez, 2016). Paraguay had its first mandate obligating the use of biofuels in 2007, with minimum blends of E18 and B1 established. In 2014, Paraguay matched Brazil´s mandates with a minimum ethanol content of 25% and discussed the possibility of increasing it to 27.5% to match Brazil´s proposal. However, it does not have biodiesel mandate in place (Lane, 2014). In 2015, the Paraguayan congress passed a law dictating that sugarcane should be the main feedstock for ethanol production, and other feedstock can be used only when sugarcane is no longer available (Joseph, 2015).

Peru

Peru is one of the few countries with an increasing rural population (Du and Hayes, 2009). It is present in this section because of its biodiesel mandates, which it has to supply by importing more than 65 million gallons of biodiesel a year from Argentina (Kray and Joseph, 2016).

For Peru, an important factor occurs when finding a driver for policy adoptions, which here is the price of land. Peru, along with other countries in Latin America, has become an important target for foreign investors looking to acquire land (Borras et al., 2012). Exporting biodiesel mainly to Korea, followed by Colombia, in 2016, the exports of biodiesel reached USD $74.4 million (Agrodata Peru, 2017). As of 2011, there were no ethanol programs in the country (Janssen and Rutz, 2011).

Uruguay

Although Uruguay has appropriate weather and soils for a wide range of crops to be grown, some experts and producers pointed out that soybeans was the only crop that generated significant profit (Besón, 2014), which is still low due to low commodity prices. This situation caused a decrease in soy acreage in 2014, which caused more farmers to reduce their soybean plantation in the next season. Although land with soybeans in Uruguay has decreased, this crop is still the most advantageous alternative for biofuel feedstock. Therefore, biodiesel is the biofuel they produce, since soybeans are the most important feedstock for biodiesel (Hay, 2014). With the objective of promoting biofuel production and usage, the National Fuels Administration (ANCAP) passed a mandate in 2007 (Law number 18,195) that obligates diesel to be mixed with biodiesel at 2% between 2009 and 2011 and at 5% by 2012 (Joseph, 2014). This mandate changes the scenario for soybean processing in Uruguay, since this industry had been marginal with the majority of soybean production exported as whole beans.

Even though the soybean processing industry has this opportunity to develop, experts forecast that Uruguay will still export more than 95% of its soybean as whole beans. This is because 1) the economies of scale and Uruguay's small size compared with its neighbors; 2) high energy prices; and 3) differential export taxes in Argentina, which consist of taxing soybean oil and meal 3% lower than in the form of whole beans (32% and 35%, respectively), creating an edge that results in making Uruguayan crushers less competitive (Kray and Joseph, 2016) .

Uruguay is targeting the usage of renewable fuels since a 2002 law declared biofuels a "product of national interest" and a tax exemption on any type of alternative fuel, renewables, and substitutes for fossil fuels extracted from animal or plant origin raw material. Hence, the government creates incentives for production, distribution, and consumption of biofuels (Law 17567, 2002, Montevideo Uruguay).

The original B2 policy was not obligatory until 2012, but if used it required the usage of domestic biodiesel in the blend form to promote the internal economy (Lane, 2014).

Situation of Biofuels in North America (NAFTA Members)

The three countries in North America (Canada, Mexico, and United States) can interchange biofuels and other goods duty free because of the North America Free Trade Agreement (NAFTA). This gives the freedom to Canada and Mexico to export ethanol to the US and avoid the *ad valorem* duty of 2.5%. Canada, Mexico, and the United States are the only three countries of the Americas considered by the US Chamber of Commerce as part of the group of 25 countries considered a "larger energy user group." Based on this group, an international index was created to rank these 25 countries based on their energy security risk, in which Mexico is the most energy secure, the United States is the seventh and Canada the eighth (Appendix).

Canada

According to a study conducted in 2010 by the US Chamber of Commerce, which ranked the 25 countries that make up the larger energy user group, Canada is the eighth most secure country on this list (US Chamber of Commerce, 2016). Moreover, Canada is one of the most developed countries in the Americas, and its use of biofuels is as an octane booster, not as an actual substitute for fossil fuels (Escobar et al., 2009). The biofuel industry is believed to have a positive impact in its economy growth, reporting CAN $2 billion a year (Lane, 2013). In 2010, an E5 mandate was put in place and a B2 mandate was enacted in 2012. In 2016, to meet these mandates, the country had to produce over 2 billion liters of ethanol and 400 million liters of biodiesel. Primer feedstock for ethanol in Canada is corn (77%) and wheat (23%) (Dessureault, 2016). Although the mandate for the country requires 5% of ethanol and 2% of biodiesel in the corresponding fuel, as of 2013, some provinces had opted for a higher biofuel content. British Columbia had a B3 policy looking to increase it to 4; Saskatchewan, E7.5, and Manitoba, E8.5 (Lane, 2013).

United States

The United States is the biggest consumer and producer of biofuels, represented mainly by ethanol and biodiesel (ProExporter Network, 2013).

The most important thing to analyze in the U.S. biofuels market is the strategy used to protect and maintain this market. To do so, considering how much globalization has affected the market of biofuels, it is necessary to mention the impact of trade liberalization and removal of the federal tax credit in this country for the ethanol market. Using a multimarket international ethanol model, Elobeid and Tokgoz (2008) found that the United States has very effectively protected the ethanol industry by fixing the trade barriers. The same authors showed that with trade liberalization, the ethanol market became less susceptible to price volatilization, making it less risky because the impact of removing the tax credits overrides the impact of the tariff removal.

Biofuels Sustainability

Biofuel production worldwide has sharply increased in recent years in response to oil reserves depletion, the consequent increase in fuels prices, and the confidence in biofuels. But at the same time, great controversy has emerged from the known biofuels/food competition. This phenomenon has made the term, "Life Cycle Energy Balance (LCEB)," one of the most commonly used indicators to measure biofuel sustainability, followed by quantity of fossil energy substituted per hectare, co-product energy allocation, life cycle carbon balance, and changes in soil utilization (Silva et al., 2011).

Biofuels Policies and Mandates and their Effect on Ethanol Consumption in the U.S.

Consumption of biofuels in the U.S. is not recent. There are data that show the Ford Motor Company designed its first car engine to run on ethanol or ethanol blended with gasoline in 1908. However, it wasn't until 1970s energy crisis when ethanol started to be seriously promoted in the United States. The industry of biofuels was mostly stagnant until 2000 when ethanol was identified to lower U.S. dependence on non-renewable foreign oil. Additional research concluded that ethanol emits fewer greenhouse gases into the atmosphere when it is burned as fuel, thus reducing the environmental impact. The promotion of biofuel use in preference to traditional petroleum-based transportation fuel has linked agricultural commodity markets and energy markets more closely together. Biofuel policies can involve multiple policy instruments, but studies examining their effects on biofuel feedstock and energy markets are scarce. In addition, the impact of alternative policy approaches in the context of variability in petroleum prices and supply of biofuel feedstock has received limited attention (Diggs, Policy Perspectives).

Policies and Mandates

For the previously mentioned reasons, assorted biofuel policies have been applied in the U.S., including tax credits, import tariffs, and a renewable fuel standard. The federal tax incentives have, at times, included an ethanol blending tax credit of $0.45 per gallon, a biodiesel blending tax credit of $1 per gallon, and an ethanol import tariff of $0.54 per gallon. All of these have expired. A tax credit for cellulosic ethanol of $1.01 per gallon, scheduled to expire at the end of 2012, was extended. The renewable fuel standard (RFS) is the result of two policy acts, one from 2005 and another one that expanded the former in 2007 (RFS2) (Gruenspecht, 2013).

The policies and mandates that have affected the biofuels market in the United States include the following:

1. Volumetric Ethanol Excise Credit

The Volumetric Ethanol Excise Credit (VEETC) is known as “the blenders’ tax credit” because of the benefits it gives primarily to large oil companies. It was created in 2005 as part of the American Jobs Creation Act as an incentive to encourage ethanol use in gasoline. The act provided ethanol blenders a credit of $0.51 per gallon of pure ethanol blended with gasoline. This policy was renewed in 2008 under the farm bill and reduced the tax credit to $ 0.45 per gallon of gasoline blend sold to end consumers. In 2010, the tax credit was again renewed with the goal to produce domestically 36 billion of renewable fuels by 2022. Although the tax credit was intended only for domestically produced ethanol, it also applies to imported ethanol because blenders cannot determine the origin of the ethanol they use (Devadoss and Kuffel, 2010). This tax credit expired on December 31, 2011 (Diggs, Policy Perspectives).

2. Ethanol import tariff

The import tariff was designed to offset a tax credit that benefits U.S. and foreign producers alike. According to de Gorter and Just (2008), the tax credit is an ethanol consumption subsidy, but it makes ethanol market prices increase by almost the full amount of the credit as the impact on world oil prices is small. Therefore, removing the tariff would have a small impact on U.S. ethanol prices but increase the world price by almost the full tariff. Eliminating both the tariff and tax credit would have the exact opposite effect: U.S. prices would decline by almost the tariff (equal to the tax credit) while world prices would remain essentially unchanged (de Gorter and Just, 2008).

Differences in comparative advantages between the United States and Brazil are substantial, at a level that Brazil could still export ethanol to the U.S. even after the U.S. imposed the import tariff to specifically avoid importation from Brazil (Devadoss and Kuffel, 2010). The United States finally eliminated the tariff imposed on ethanol imports in 2012 (Doku and Di Falco, 2012). The 45-cents-per-gallon tax credit to blenders was also removed the same year.

3. Renewable Fuel Standard

Renewable Fuel Standard (RFS) is responsible for a small part of the total reduction of fossil fuel imports. (Gruenspecht, 2013). Under the Energy Policy Act of 2005, a Renewable Fuel Standard (RFS1) was created in the United States that required 2.78% of gasoline sold in the U.S. in 2006 be renewable fuel. This requirement for RFS1 was revised and finalized by the EPA in 2007.

The United States expanded usage of renewable fuel with the Energy Independence and Security Act (EISA) of 2007. It came with a provision for a new Renewable Fuel Standard (RFS2), which increased the required volumes of renewable fuel to 36 billion gallons by 2022 or about 7% of expected annual gasoline and diesel consumption above a business-as-usual scenario. The act gave the EPA the authority to revise and implement regulations related to RFS2 (Center for Climate and Energy Solutions). This expansion of the mandate, or RFS2, caused a persistent growth of 30% in global corn prices (Carter et al., 2012; Walls et al. 2011).

With ethanol production 6% higher than in 2016 thanks to the RFS, this program is believed to be at risk since the current U.S. administration has chosen Scott Pruitt as the head of the EPA. Pruitt has historically fought against biofuels and now would have the authority to invoke a waiver to the RFS to lower the volume of ethanol required to be blended into the gasoline sold in the U.S. If this happened, an oversupply of ethanol is likely to occur (Rapier, 2017).

Mexico

Mexico is the most energy secure of the larger 25-country energy group classified by the US Chamber of Commerce (US Chamber of Commerce Fundation, 2016). With 99.2% of the population having access to electricity and as one of the countries with fewer people living in slums (Butera et al., 2016), Mexico has one mandate in place but it only applies in one city, Guadalajara, in the State of Jalisco. It consists of obligating local merchants to sell gasoline with a minimum of 2% ethanol content. The government plans to extend this mandate to Mexico City and Monterrey (Lane, 2014). Mexico, along with Ecuador, Peru, and Bolivia, has made progress on biofuel production, but not significant progress. For this reason, Mexico has not published any standard for biofuels yet, but since this country is planning to supply the U.S. with biodiesel, it is expected that they meet the ASTM D6752 standard, which is one of the standards established to ensure quality of biodiesel in the U.S. (Rutz et al., 2015).

To take advantage of NAFTA, which would allow Mexico to import ethanol from the U.S., the Mexican government was projecting to start permitting ethanol to be blended in local gasoline up to 5.6% for use as an octane booster. A 5.6% blend of ethanol in Mexican gasoline would create a demand of 475 million gallons a year, and Mexico has the capacity to produce 66 million gallons (mainly from sugarcane). The rest was planned to be purchased from the US. In 2016, after some tension created after Donald Trump was elected, Mexico, which imported about 18 million gallons of ethanol from the U.S. in 2016, remains uncertain about taking advantage of this new policy (The Barrel, 2016).

This chapter reviewed some of the aspects in which this paper is focusing on regarding biofuel use and related policies. With a better understanding of biofuel usage and policies, and their effect on other topics of concern, the next step is to review different studies conducted to analyze not just the impact of biofuels, but also to find determinants to adopt these types of policies, which will be covered in chapter IV.

CHAPTER III. LITERATURE REVIEW

The purpose of this paper is to identify the drivers for incorporating biofuel policies that countries in the Americas and the Caribbean have in common. For this, it is important to analyze what countries have more dependency on oil coming from other countries, state of the art in biofuel usage in each country, environmental protection positions, and economic indicators and other parameters related to the biofuel markets. In this chapter, we review recent studies that focus on how ethanol affects the fossil fuels market and the role of biofuel polices in this interaction.

Impact of Ethanol on Gasoline Market

Ethanol is often considered a substitute for gasoline; in fact, it has been shown to have a significant, though slightly negative, effect on gasoline prices, as demonstrated by Du and Hayes (2009) in a study that included welfare analysis to consider the U.S. ethanol market.

To clearly understand the interaction between gasoline and ethanol, Debnath et al. (2017) used an international ethanol model to describe ethanol demand, considering the ratio of ethanol and gasoline sales in Brazil against the ratio of ethanol retail price to gasoline retail price in the same country. Using data from 2010 to 2015, the authors claim that this figure very well represents the ethanol market worldwide. Among other objectives, the authors focused on modeling the alternating complementary and substituting relationship between ethanol and gasoline simultaneously. With this structural economic model, they used the blend E10 as a complement to gasoline, and as a substitute if the blend content was more than 10% ethanol. According to this, ethanol use in countries with biofuel policies in place is elastic when the gasoline price is high, allowing for a substitution effect; and inelastic when the gasoline price is low relative to the ethanol price, representing a complementary effect. This situation generates a kinked ethanol demand curve (Figure 4), representing petroleum price at the location of the kink.

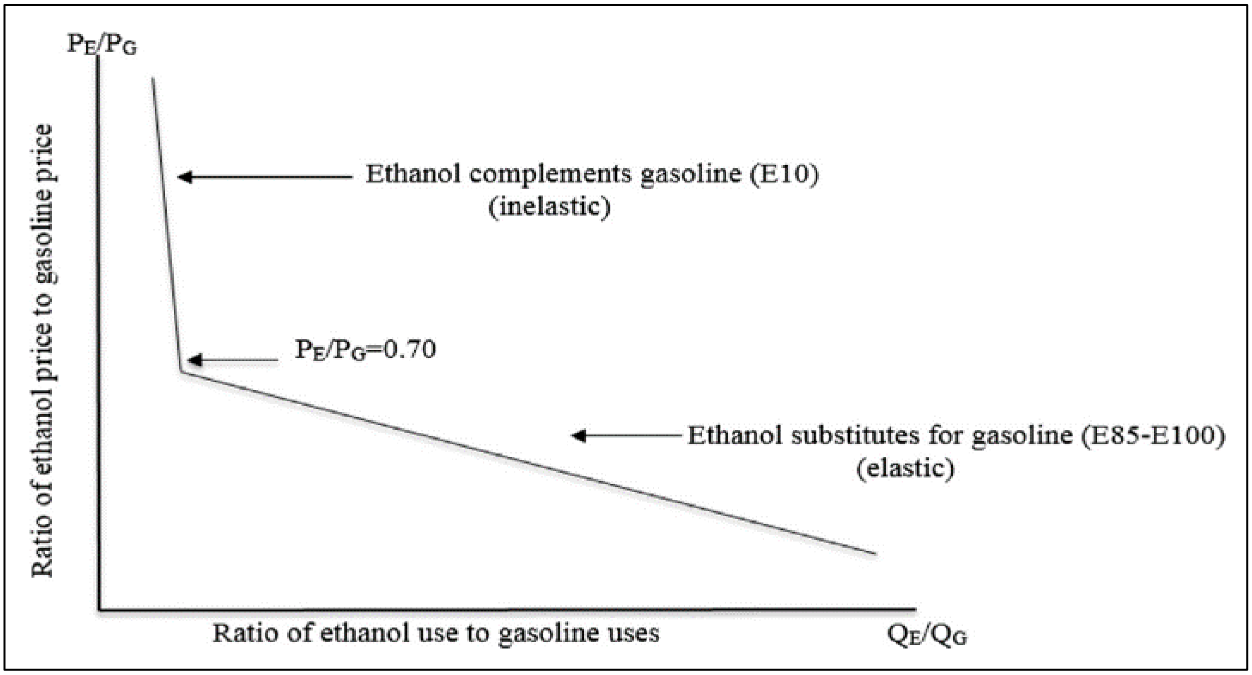

Figure 4. Kinked ethanol demand curve
Source: Debnath et al. (2017).

In figure 4, P_E, represents price of ethanol; P_G, price of gasoline; Q_E, quantity of ethanol; and Q_G, is the quantity demanded of gasoline.

The following equation can be used to explain the use of ethanol in Brazil as well as in the rest of the countries with biofuel polices:

$$Q^E = Q_L^E + Q_H^E$$

$$Q_L^E = \alpha - \beta\left(\frac{P_E}{P_G}\right) \sigma < \left(\frac{P_E}{P_G}\right)$$

$$Q_H^E = \lambda - \rho\left(\frac{P_E}{P_G}\right), \left(\frac{P_E}{P_G}\right) \leq \sigma$$

Where, Q^E is ethanol use, Q_L^E and Q_H^E represent lower (0%-10%) and higher (85%-100%) ethanol blend, respectively. Lower and higher blend ethanol equations represent ethanol demand based on relative prices of ethanol (P_E) to gasoline (P_G). In the equations, α and λ are the intercepts, and β and ρ are price coefficients for lower and higher ethanol blend. Finally, σ is the ratio of prices at which consumers switch from low to high ethanol content blends (Debnath et al., 2017). Similarly, Luchansky and Monks (2009), after conducting a two-stage least squares regression with data related to biofuels from 1997 to 2006, concluded that ethanol supply price has an inelastic response, which coincides with Rask's (1998) conclusions. It is clear that both authors could only capture the inelastic part of the curve, and the inelasticity might come from the MTBE ban that some states had already activated (Luchansky and Monks, 2009). The authors also found that corn prices are not consistently significant related to ethanol prices, and the lone significant result yielded an elasticity of 0.121.

Further analysis on price elasticities was conducted by Keeney and Hertel (2009). They conducted a review of the literature and methods used to make estimates of yield elasticities on corn in the United States because of its use and policies. This was to determine the elasticity on corn yields to a change in demand coming from the biofuel policy, and to show that zero yield response should not be assumed. For comparison, the authors focused on the values they considered "low response" as results of previous studies found in the investigated literature, ranging from values from 0.22 to 0.28 for elasticities (see Table A-2 in the appendix).

In order to better understand the implications of price and feedstock-yield relationship in policy models, the author used a model of factor supply and demand expressed in terms of elasticities and percentages of changes in price and quantities (p and q in the following three equations) using the case of a producer under locally constant returns to scale earns zero economic profit and with conditions of perfectly elastic demand (exogenous commodity prices). Percentage changes in input and output prices (r,p), commodity output (q), and factor supplies and demands (x^s, x^d) are determined by the equilibrium model, following an output price shock. Land use change is captured by supply elasticity of input i to a particular crop in response to a change in the factor returns (η_i). Substitution between two factors is captured by $\sigma_{i,j,}$ which is the Allen Uzawa elasticity of substitution (AUES). Finally, initial cost shares of inputs are denoted by c.

$$x_i^s = \eta_i r_i$$

$$x_i^d = \sum_j \sigma_{i,j}\, c_j r_j + q$$

$$p = \sum_j c_i\, r_i.$$

Solving the three equations above considering market equilibrium $\left(x_i^s = x_i^d\right)$, for the change in q from an exogenous shock to p. This way, the own price supply elasticity is obtained. The commodity supply elasticity is obtained in the below equation in which 1_n is a summation vector, Σ is the symmetric matrix of AUES for the quasi-fixed factors of production, and Ω represents a diagonal matrix with elements $\eta_i c_i^{-1}$.

$$\mathcal{E} = -\left[1_n'[\Sigma - \Omega]^{-1}\, 1_n\right]^{-1}.$$

From this last equation, it is possible to appreciate that the assumptions on factor mobility are critical in determining a response to price changes. The authors agree with the most modern models they analyzed using techniques similar to the equations above, in which the obtained results for elasticities are close to 0.25 (Keeney and Hertel, 2009).

Elobeid and Tokoz (2008) conducted sensitive analysis testing responses with different elasticities for sugarcane ethanol production in Brazil to the U.S. and Brazil ethanol demand. With elasticity unchanged, the sugarcane industry responded to higher ethanol prices by allocating more sugarcane for sugar production, causing a reduction in sugar prices in the world market. But with higher elasticities, like the original scenario, the increase in ethanol production was larger, so more sugarcane went to ethanol production, making the price of sugar higher.

With the hypothesis that the adoption of biofuel has an impact on oil prices, and therefore total fuel consumption, by decreasing or decreasing depending on the policy regime and market conditions, Rajagopal et al. (2010) used a two-region model of the global oil market to show that the net change in global fuel consumption, because of policy adoption, can have a significant impact on net GHG emissions. They divided the regions, leaving one of them for the effect of the implementation of a domestic biofuel mandate and the other region without this effect. To achieve this, the authors computed what they called an indirect fuel use change (IFUC). Under a given policy, the previously mentioned model was developed for the world oil market, for which they assumed the existence of only one type of fossil fuel, oil, and represented in their calculation as o, and one type of biofuel denoted as b. It was also assumed that oil and biofuel are perfect substitutes. For the world market, the two regions were named "home" and "abroad," represented by h and a, respectively, in the equations below. Letter w denotes price, consumption, or emissions at the world level, while S and S^{-1}, the fuel supply function and the inverse supply function. D and D^{-1} represent the same but for the demand function. Price of fuel and the quantity consumed were denoted by the letters p and q, respectively, and Z the GHG emitted. The presence of biofuel policies was indicated by 1, and 0 otherwise. Finally, γ indicates the average direct lifecycle carbon intensity, assuming that $\gamma_b < \gamma_o$. In the study, the market clearing condition in the absence of policy intervention is given by (some equations skipped):

$$q_{o0}^{w} + q_{b0}^{w} = q_{0}^{h} + q_{o}^{a}$$

The total emissions factor is computed as the following:

$$Z_0^w = \gamma_o q_{o0}^{w} + \gamma_b q_{b0}^{w}$$

And the total emission under policy:

$$Z_0^w = \gamma_o q_{o1}^{w} + \gamma_b q_{b1}^{w}$$

Where, $q_{01}^{w} = q_{o1}^{h} + q_{b1}^{a}$.

Finally, to calculate the net change in global GHG emissions in a scenario with an active policy, the sum of the change in emission at home and abroad are considered as follow:

$$\Delta Z^w = Z_1^w - Z_0^w = \gamma_0 (q_{o1}^{w} - q_{o0}^{w}) + \gamma_b q_{b1}^{h}$$

$$= (\gamma_b - \gamma_o) q_{b1}^{h} + \gamma_o \left(q_{o1}^{w} - q_{o0}^{w} + q_{b1}^{h}\right)$$

Where $(\gamma_b - \gamma_o) q_{b1}^{h}$is the replacement effect that causes reduction in emission and $\gamma_o \left(q_{o1}^{w} - q_{o0}^{w} + q_{b1}^{h}\right)$ is the reduction in emissions due to the IFUC effect (for more details, see Rajagopal et al., 2010).

The authors conclude that predictions modeling indirect effects of different policies differ when analyzed in a general equilibrium context as opposed to a partial equilibrium. They attribute this to the increase in the burden of government finances coming from the subsidy. In a general equilibrium analysis of exogenous biofuel subsidy, this would have to be followed by an (endogenous) increase in taxes in other sectors of the economy, in which the effect would reduce the consumption of the associated goods, services, and emissions. If the tax rate is constrained to be fixed, the subsidy would reduce the provision of public goods and services, although lowering emissions would also have a negative impact on low-income families that depend on government services (Rajagopal et al., 2010).

Price interactions occur not only between gasoline and ethanol. Zhang et al. (2007) revealed that limit price competition was at least one of the reasons why bioethanol could not enter the U.S. market before MTBE was restricted. Then corn-ethanol refiners in the U.S. did not have incentives to improve efficiency, which limited the U.S. ability to compete with sugarcane-based ethanol refiners from Brazil (Zhang et al., 2007). At the same time in the U.S. market, per Du and Hayes (2009), ethanol production has a significant influence on fossil fuel commercialization. The authors show that ethanol production kept wholesale gasoline prices $0.14/gallon lower than they would be with no ethanol. In addition, the elasticity of ethanol with respect to MTBE (ethanol substitute), prices fluctuates between 0.327 and 0.478. This represents a considerable reduction in price sensitivity, which the authors attribute to the increasing number of states that have banned MTBE as a gasoline oxygenate and used ethanol as a substitute (Luchansky and Monks, 2009).

Impact of Policies on Biofuels Market

As mentioned, the MTBE ban in the United States facilitated the entrance of ethanol to the fuels market. The import tariff is a matter of interest as it is also a biofuel policy. It was set at $0.57 per gallon with a specific tariff of $0.54 and 2.5% ad valorem. Thus, the import tariff exceeded the tax credit by 11 cents per gallon of ethanol. Even though this tariff was imposed to protect the ethanol market in the United States from importing too much ethanol from Brazil, this country still had many comparative advantages over the United States, so Brazil kept exporting to the United States when the tariff was still active (Devadoss and Kuffel, 2010).

With the intention of analyzing comparative advantages within countries with biofuel policies in place, Doku and Di Falco (2012) tested for possible drivers for biofuel policies using an OLS and probit panel estimations with country dummy variable, equivalent to a fixed effect model to control for individual country differences, focusing on ethanol polices only. The authors concluded that different countries have different drivers for biofuel polices and that development seems to be a determinant factor on what type of variables influence policy adoption. GDP resulted to be much more significant for OECD countries than for the non-OECD ones, which was interpreted as a naturally endowed comparative advantage as land is not as necessary for OECD countries as it is for non-OECD countries. This deduction was made based on the differences in the significance of the land variable between OECD and non-OECD countries as well (Doku and Di Falco, 2012).

To study the effect that policies to incentivize ethanol usage have on crops and cattle prices, Bastianin et al. (2016), used monthly time series data of nominal spot prices of ethanol (and other feedstocks) and cattle recorded in Nebraska from 1987 to 2012. From this they conducted an empirical analysis to account for the long-run co-integrating relationship level between the price of ethanol and cattle (among others), as well as short-term granger causality and predictability links based on returns. After implementing an out-of-sample evaluation of price models, the authors learned that ethanol was predictable using crop prices, but crop prices cannot be predicted using ethanol, and concluded that there is no evidence that ethanol returns a granger-caused food price variation.

As previously mentioned, biofuel polices are often said to have environmental enhancement purposes. By developing a lifecycle economic analysis (LCEA) that integrates endogenous input substitution of biofuel, Liu et al. (2017) examined the impacts of carbon tax and revenue-neutral tax-subsidy policy on lifecycle greenhouse gas emissions from cellulosic ethanol using forest residues as feedstock. To allow for input substitution in the cellulosic ethanol feedstock, conversion, and transportation process, the authors considered energy substitution coming from woody biomass for coal in the cellulosic ethanol conversion plant, biodiesel for diesel in feedstock production, and feedstock and ethanol transportation, as well as substitution of capital and labor for energy in all stages of the lifecycle. The authors concluded that both evaluated policies can considerably reduce carbon emissions if substitution among inputs is induced. This conclusion is based on the belief that there is no net emission from combustion because feedstock growth sequesters carbon at the same rate that fuel combustion emits it (Liu et al., 2017).

With the belief that second-generation biofuels will play an important role in the future of the biofuels market, Ribeiro et al., (2017) analyzed market share penetration of advanced biofuels and modeled economic, political, and technological variables crucial to the adoption of this type of biofuel. These authors used stochastic automata networks to model future scenarios for the transportation fuel markets under different policy alternatives from 2010 to 2040. Representing discrete and continuous time Markovian models, they evaluated the interplay among different policies (subsidy, taxes, R&D investments, and mandates) and concluded that R&D is the most important factor policies should focus on.

This chapter used different economic theories and methodologies adopted by different authors in their studies to analyze the interaction between ethanol and gasoline in the fuels market and how and when they interact as complements or substitutes based on their elasticities. The effect of different policies, such as blend mandates and tariffs, were also analyzed.

The explanation was used as a background for the election of the model and data for the present study. In the next chapter, methodology and data used for the present study will be presented and explained.

CHAPTER IV. METHODS AND DATA

With the objective of finding the main drivers that countries in the Americas and the Caribbean have in common to adopt biofuel policies, 27 countries have been selected based on their presence in the region, evident importance in the biofuel markets, and information availability. For this, a logit regression with panel data arrangement and a random effect model is used.

Theoretical Model

Panel Data

Panel data are the combination of times series and cross sectional data. This allows us to statistically analyze published information, such as what is available in the World Bank web site and other sources that have annual information for multiple countries, such as the Food and Agriculture Organization of the United Nations (FAO), the US Energy Information Administration (EIA), and others. For this study, the analysis will be conducted using countries of the Americas using the empirical model created to work with time series information from firms, states, countries, or industries simultaneously. There are two famous cases where panel data sets were used: the National Longitudinal Survey of Labor Market Experience (NLS) and the Michigan Panel Study of Income Dynamics (PSID). In the latter, information of about 6,000 families and 15,000 individuals was analyzed (Greene, 2002).

To conduct the empirical analysis to test for the drivers of biofuel polices, 25 years of data related to biofuels policies from 27 countries in the Americas were arranged as a panel data. Panel data, also called longitudinal data, were created to relate time series to each cross section in the data set (Wooldridge, 2013). This data analysis allows us to control for variables that are difficult to control using other methods; these variables include business practices, cultural factors, etc. across different entities: companies, individuals, or countries (Torres-Reyna, 2007).

An advantage that panel data have over other arrangements, like cross sectional data, is that with the former, repeated measures over time can be done and analyzed, and not only one at a time point like in the latter; so cross sectional data can be observed at several points in time (Greene, 2003). This way, information regarding the complete selected period is taken into consideration (Brüderl, 2015).

Binary Logistic Regression

When y is a binary variable taking on the values zero and one, it is always true that $P(y = 1|x) = E(y|x)$; the probability of "success," which is the probability that $y = 1$, is the same as the expected value of y. Thus, the equation to obtain is the following:

$$P(y = 1|x) = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k$$

In this case x represents the full set of explanatory variables.

The above equation says that the probability of success, say, $p(x) = P(y = 1|x)$, is a linear function of any value x. This equation is an example of the binary response model, and $P(y = 1|x)$ can be also called the response probability. This equation represents a multiple linear regression model with a binary dependent variable, therefore called a linear probability model (LPM). In an LPM, the response probability is linear in the parameters β_j, which measures the change in the probability of success when x_j changes, holding other factors fixed (Wooldridge, 2003).

Therefore, this model was chosen for this model because the binary variable choice will allow for conditioning the model to have a response regarding the likelihood of adopting biofuel policies or not, based on 25 years of data by 27 different countries in the Americas. With this purpose in mind, the information related to biofuel policies of all countries in the Americas and the Caribbean region were introduced to create a data set that contain information of countries with biofuels, as well as countries that adopted biofuel polices during the time period used for this analysis, and countries that neither had nor adopted these types of policies during the selected time period.

By including binary variables, it is possible to include quality variables into a multiple regression model. In practice, with binary outcome, the dependent variable ‘y’ takes only two possible values, 0 or 1, representing the existence or non-existence of a specific quality, in this case, the existence or non-existence of a biofuel policy in each chosen country (Wooldridge, 2013). In other words, binary variables are a convenient means of building discrete shifts of the function into a regression model, which is very useful when discrete outcomes, like adoption or non-adoption of policies, need to be analyzed. An important policy analysis issue concerns the measurement of such treatment effects when the dummy variable results from an individual participation decision (Geene, 2003) regarding countries in the present study.

A binary variable that takes the value 1 for only one observation, has the effect of deleting that observation from computation of the least squares slopes and variance estimator, but not from the calculation of R squared (Greene, 2003).

The binary response model is utilized to overcome the limitation of a linear probability model (LPM); the two most important disadvantages of LPM are that the fitted probabilities can be less than zero and greater than one, and the partial effect of any explanatory variable is constant.

Because of the non-linear nature of this model, ordinary least squared (OLS) or weighted least squared (WLS) cannot be used to estimate the binary response (though a non-linear version of these estimators could be used). For this case, maximum like likelihood estimation (MLE) will be used, being the most appropriate for logit regressions. MLE is an estimator that maximizes the (log of) the likelihood function. Because MLE is based on the distribution of y given x, the heteroskedasticity in Var(y|x) is automatically accounted for (Wooldridge, 2013).

The distribution on logit and probit models are very similar, and although probit is most commonly used because normal distribution can be assumed, in this project logit for practical reasons, the statistical program did not become solved when probit was used. This could have happened because the adjusted values respond better to a logit rather than probit distribution.

Random Effect

The two most common alternatives to be used to estimate the significance in panel data are fixed effect and random effect. With a fixed effect model, the effect of the unobserved individual is considered correlated with the variables included in the regression. This model is usually viewed as applying only to the cross-sectional units in the study, to anyone out of the sample. But if the individual effects are uncorrelated with the regressors, then it is better to model the individual specific constant terms as randomly distributed across cross-sectional units, using a random effect model (Greene, 2002).

For this paper, panel data with a random effect model were used. This model is used when the unobserved effect is thought to be uncorrelated with all explanatory variables (Wooldridge, 2013). The random effect model assumes that individual specific effect is a random variable that has no correlation with the explanatory variables (in this case, individual effect refers to the effect of each country´s variables for every year of data). Constant variance of the individual effect is also assumed, as well as that the regressors including a constant are not perfectly collinear, and that the regressors have non-zero variance with not too many extreme values (Schmidheiny, 2016).

In order to test if our intuition (previously explained) is consistent with what test to determine if a fixed or random effect should be used, a Hausman test was conducted, shown in Table 2, confirming that random effect is correct to use by rejecting the existence of a close correlation between variables.

Table 2. Hausman test

Variable	Fixed (f)	Random (F)	Difference (f-F)	S.E.
Oil reserve	54654.90	20295.52	34359.38	20526.70
Arable Land	0.70	0.18	0.52	0.56
GDP	8.19e-14	-3.47e-14	1.17e-13	6.31e-14
Military Expense	3.90e-14	3.07e-14	8.32e-15	9.49e-15
Rural Employment	4.43×10^-3	9.49×10^-4	3.49×10^-3	2.90×10^-3
Food Index	7.94×10^-4	6.25×10^-4	1.69×10^-4	7.22×10^-4
Ethanol Production	9.65×10^-4	2.17×10^-3	-1.21×10^-3	3.56×10^-4
Oil Production	-3.14×10^-5	6.31e-06	-3.77×10^-5	7.72×10^-5
Gas Price	0.21	0.17	0.04	0.07

Note: f= consistent under Ho and Ha, obtained from xtreg; F= inconsistent under ha, efficient under Ho, obtained from xtreg.

Conceptual Framework

In this study, our panel data will be unbalanced due to missing data for some variables, mostly for some countries in Central America. For a logit unbalanced panel with random effect mode, an equation like the following should be obtained.

$$\text{Policy}_{it} = \beta_0 + \beta_1 X_{it1} + \beta_{2Xit2} + \ldots + \beta_k X_{itk} + a_i + \mu_{it}$$

Where, Policy = Likelihood of policy adoption (binary); β is the coefficient of the regressors X for each group of country i and year t. The letter k denotes the order of the continuation of variables. Finally, a represents the unobserved effect and μ, the unobserved term.

It is important to identify the reason why the panel is unbalanced, because it could lead to biased estimators. If the reason a firm (or country) leaves the sample correlates with an idiosyncratic error (unobserved factors that change over time affect y), the sample section can result in biased estimates. This is why the a is present in the above equation, to capture the unbalanced effect. Unlike fixed effect, random effect does not allow for the correlation between a and X_{itk} to exist.

Unlike a fixed effect model, with random effect there is no need to eliminate a_i because it is thought to be uncorrelated with each explanatory variable in all time periods. Then, using a transformation to eliminate a_i could result in efficient estimators. Under this assumption, a_i being uncorrelated with the explanatory variables, the above equation becomes valid for our random effect model.

Data

Data for this work were obtained from the Food and Agriculture Organization of the United Nations (FAO, 2017), International Energy Statistics Data (EIA) and The World Bank's World Development Indicators.

A 25-year time series range is used, taking data from 1991 to 2014 for 27 countries with and without biofuel policies in place will be used. The dependent variable is the adoption of bioethanol policy; for this binary outcome, a number 1 is given if the country has a policy in place (starting from the year when the policy was adopted), or 0 otherwise. The countries under evaluation are Argentina, Belize, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad y Tobago, The United States, Uruguay and Venezuela. These countries were chosen for being good representations of the Americas. The sample has all the countries with biofuel policies in the region, including those that have an impact on the biofuels market, and others that do not have a broader prospective in the model.

Empirical Model

In order to address the study's objectives, many alternative empirical analyses were conducted. Different dependent variables and data adjustments were explored. In general, results of these analyses did not demonstrate statistical significance. Thus, this thesis focuses on the analysis of determinants of national biofuel policies.

The empirical model is constructed using the following explanatory variables for each country:

1) Oil reserve per capita, in billion barrels; 2) arable land per capita, measured in hectares of land under temporary crops; 3) gross domestic product (GDP), constant in 2010 USD; 4) military expenditures (in current LCU); 5) employment in agriculture (percentage of total employment); 6) food production index, food crops that contain nutrients (considers production of 2004-2006 as 100%); 7) ethanol production (thousands of barrels per day); 8) Oil production (thousands of barrels per day); and 9) gasoline price (USD per liter).

The statistical software STATA® 11.2 is used to run the longitudinal panel data with the time series and binary outcome. An unbalanced panel will be conducted since much of the country has many years of missing data. With this data and software, the following equation will be estimated:

$$\text{Policy}_{it} = \beta_0 + \beta_1\text{Oilreserve}_{it} + \beta_2\text{Arablep}_{it} + \beta3\text{GDP}_{it} + \beta_4\text{Milexpen}_{it} + \beta_5\text{Empl}_{it} + \beta_6\text{Foodindex}_{it}$$

$$+ \beta_7\text{Etprod}_{it} + \beta_8\text{Oilprod}_{it} + \beta_9\text{Gasprice}_{it} + a_i + \mu_{it}$$

Where, Oilreservep = oil reserve per capita; Arablep = arable land per capita; GDP = gross domestic product; Milexpen = military expenditure; Empl = rural employment; Foodindex = food production index; Etprod= ethanol production; Oilprod = oil production; Gasprice = gas price; each of them estimated for country i at time t.

Expectations

Oil reserve is not necessarily a good indicator of the oil business since, as is commonly known, some countries have low oil production relative to their oil reserve, as is the case for Venezuela, or the opposite scenario for the United States. However, oil reserve should still have a considerable correlation with the oil industry, and under an energy security standpoint, oil availability should offset the need for biofuels. Therefore, the variable "oil reserve" is expected to be negatively significant.

Since biofuels come from extensive crops, the variable "arable land" is expected to be positive and significant because it is assumed that any country would produce food crops with more priority over any crop used for non-food production. Thus, the primary driver for land allocation would be food crops, and if the country still has land available after producing food, it could consider growing crops for biofuels.

Although the driver for biofuel policies are under analysis, it is assumed that production of biofuels is not meant to satisfy basic needs, and it requires significant investments to process them. This generates the assumption that if a country has biofuel polices in place it is because its basic needs should be covered. Therefore, for a country to have biofuel policies in place or even in prospect, it should count with economic stability. Thus, it is expected that the variable "GDP" will be positive and significant, since a country with a higher GDP it is more likely to be economically stable.

In line with GDP, military expenditure was taken into consideration for being a variable closely related to economic stability. It was assumed that if a country spends a considerable amount of money on military activities, it is because at least most of the basic needs are covered. For this reason, it is expected this variable will be positively significant, because if a country has most of its basic needs covered, it is more likely that this country can afford to have biofuel policies.

Rural employment as a variable could have different impacts in different countries. In developed countries, biofuel feedstock are not as dependent on rural labor as they are in undeveloped countries (Doku and Di Falco, 2012). But since there are more undeveloped than developed countries in this model, it is expected that the overall effect of this variable will be positive and significant, since more labor available in rural areas makes it easier to grow biofuel crops, and thus, more likely to lead to biofuel polices.

The variable “food index” was chosen as an indicator of food security, thinking that the more nutritious food produced in a country, the greater its food security. This makes it more likely to adopt biofuel policies since a basic need as food is covered, minimizing food imports, it becomes easier for this country to pay for the investment involved in having biofuel policies. Hence, it is expected “food index” to be positive and significant for this model.

Ethanol production is expected to be one of the most important variables since this is the biofuel used for this analysis, and the more ethanol a country has, the more likely it should be to have policies in place to make sure the available resources are taken advantage of before importing goods.

Assuming that with more oil production, a major percentage of the country´s GDP comes from this industry, it could also be assumed that the country will have less interest in adopting biofuel policies. For this reason, the variable “oil production” was added to the model, expecting it to be negative and significant.

Many authors indicate that gasoline prices are closely related with the presence of biofuels in fuel markets (Vedenov et al. 2006; Tatum et al. 2010; Laurini 2017). This makes the variable gasoline prices expected to be positive and significant for the present model. Feedstock prices are expected to be positive and significant because the higher they are the more expensive it gets to produce ethanol and vice versa (Doku and Di Falco, 2012).

After describing the methods and data used to develop this research project, it is possible to continue with the next chapter, in which the result will be analyzed in order to contrast the expectation with what was obtained after running the model previously described.

CHAPTER V. RESULTS

With a clear understanding of how the panel data were conformed data explained in the previous chapter, the obtained results will be explained in Chapter V.

From the results obtained from the panel data, out of the 13 variables used, 6 were in line with expectations: arable land, GDP, ethanol production, feedstock prices, military expenditure, and food index. Table 3 shows the results of the analysis of the 27 countries analyzed using a panel data with random effect and logic model (table with means and standard errors in the appendix).

Table 3. Logit regression for biofuels policies adoption in Latin America

Policy	Coefficient	Std error	Z	Confident Interval	
				------------------95%-----------------	
Oil Reserve	-2,212,788	2,844,581	-0.78	-7,788,064	3,362,487
Arable Land	19.25**	8.87	2.17	1.86	36.64
GDP	-1.18e-11**	4.79e-12	-2.46	-2.12e-11	-2.39e-12
Military Expense	1.94e-12***	5.62e-13	3.45	-8.39e-13	3.04e-12
Rural Employment	0.13	0.24	0.53	-0.35	0.61
Food Index	0.47**	0.15	3.05	0.17	0.77
Ethanol Production	0.52**	0.18	2.93	0.17	0.86
Oil Production	0.01**	0.00	1.94	0.00	0.02
Gas Price	13.62**	5.67	2.40	2.50	24.75
Constant	-96.11	22.25	-4.32	-139.73	-52.49

*Significant at the 0.01 probability level.
** Significant at the 0.05 probability level.
*** Significant at the 0.001 probability level.

Oil Reserve

The more benefit a country receives from the oil industry, it is expected to have less interest in having substitutes for fossil fuels. In addition, oil reserve have a close correlation with oil production, so both of these variables were expected to be significant. The result in this study show otherwise, which could suggest there are other factors driving the biofuel policies adoption, such as economic risk mitigation, as concluded by Doku and Di Falco (2012). It must be taken into consideration that these outcomes are intended to represent the entire region, and in the model, many countries that don't produce oil were included, and so the effect of this variable could have been attenuated. Although, in an attempt to test for the effect of Venezuela in this model, the same test was run taking this country out of the regression, but the variable oil reserve was still non-significant.

Arable Land

The variable available land was, as expected, positive and significant, which indicates that more land available for agriculture makes a country more likely to have biofuel policies. This coincides with Doku and Di Falco (2012). In their study, also using panel data, they analyzed OECD countries and non-OECD separately. The outcome for land availability in the present report, was also supported by Swaminathan in 2013, and it is attributed to the competition for other agricultural activities that are, for the most part, designated to produce food. Thus, with more land available in a country, it is more feasible to incentivize biofuel usage, since food crops are assumed to have priority.

GDP

The variable GDP was significant as expected, but surprisingly it was negative. The variable was put in the model squared to test for a U-shaped relationship between GDP and policy adoption, but the model indicated that the variable squared GDP remained negative and significant. Also, GDP per capita was evaluated in the model as well to verify if it would vary in this way, but the variable still showed a negative effect. No good explanation is found for this not expected result, but as concluded by Doku and Di Falco (2012) (for a different variable), it is possible that the relationship between GDP and the likelihood of the adoption of a biofuel policy for the present model, doesn't have a linear correlation.

Military Expenditure

Military expenditure was included, as previously explained, as an indicator of economic stability, and as expected, it was found to be positive and significand. It is therefore accepted that the existence of biofuel policies in a country can be considered, in general terms, as a sign of a good economic stand.

Rural Employment

An empiric proof of this variable affecting rural employment is that the VEETC policy was created under the American Job Creation Act (Diggs, 2012). In this case the policy was put in place to stimulate the U.S. economy by increasing nation's biofuel production. However, in the present study, this variable becomes non-significant. The reason for this variable not being significant in the present model was associated with the number of countries accounted for in the model in which the feedstock does not depend directly on rural employment. This is because the edaphoclimatic characteristics allow crops that can be easily grown with machinery, which is supported by proper country development that allows the use of modern equipment that can be handled by few people. These results come from several countries with different economic development and realities, as well as from different feedstock and edaphoclimatic conditions. As explained by Hunsberger et al. (2017), the socio-economic effect and expectation of biofuels should be evaluated under different circumstances and along several dimensions, such as by scale, time frame, and social characteristics.

Food Index

The variable food index met the positive significance expectation, proving that the more food secured a country is, the greater the likelihood of the country to adopt a biofuel policy. This agrees with Rathmann et al. (2010), who postulate that production of biofuels increases food prices. If adopting biofuel policies increases the price of food, it can be considered under certain circumstances as a thread for food security. Therefore, the higher the number representing the food index, more likely a country will adopt a biofuel policy to incentivize biofuel production, all other variables held constant.

Ethanol Production

As expected, ethanol production was also statistically significant and positive. This is associated with the capacity of a country to produce ethanol, because to establish a bioethanol policy or mandate, the government of a given country must consider how much ethanol is capable of being processed prior to setting a number for minimum requirements in the blend, tax, or incentive. From a theoretical point of view and focusing on the biofuels market in Brazil, Stattman et al. (2013) use examples that are in line with this result on biofuel production and biofuel policies.

Oil Production

Oil production is expected to be significant but not positive, since it was assumed that oil production offsets the likelihood of adopting biofuel polices because of its correlation with energy security. This is surprising because ethanol is a substitute for the two most commonly used fuels derived from crude oil (EIA, 2013). This result suggests that oil production, for the

Americas, not only does not behave as a substitute, but it could provide an incentive for biofuel policies adoption. This could be due to the presence of countries that either do not produce oil or do not produce enough so they still have to import and create biofuel policies. It could also be because of external factors, such as environmental damage mitigation strategies when countries use biofuels.

Gasoline Price

Being that gasoline is the product ethanol aims to substitute for, it is often believed to be the main dependent factor on ethanol commercialization or policy adoption in a country (Vedenov et al., 2006; Laurini, 2017). In line with these authors, this variable was a significant factor in the adoption of ethanol polices. It is also important to consider that the existence of biofuel policies is highly influenced by endogenous factors, and policies are often imposed because, under free market assumptions, biofuels would not compete effectively (Anderson, 2012).

After analyzing some surprising results in this chapter, a trend on what are the most important determinants for biofuel policy adoptions in the Americas can be perceived, which will be covered and further interpreted in Chapter VI.

CHAPTER VI. CONCLUSIONS

This chapter interprets the results obtained and presented in chapter V, in order to finalize this study focusing on drivers for the adoption of biofuel policies in the Americas when all countries are analyzed and used to build one model.

The determining factors for the adoption of biofuel policies have different origins and normally do not respond to free market assumptions, because they depend on the existence of policies. Policies oriented to increase biofuel production are, for the most part, created to protect local markets. Although, in some cases, biofuel policies have created opportunities for lower income countries to become biofuel exporters, like the case of Caribbean countries exporting ethanol to the United States for the latter to meet its own biofuel mandates. This allows these countries to benefit from trade agreements, backed by their comparative advantages.

Apart from the variables of oil reserves and rural employment, the results were consistent with our expectations. It was surprising to see variable military expenditures being the most influential variable with 99% confidence (Table 3). Also, this variable resulted not to be as closely correlated as expected with GDP (Table A-4), resulting in a different significance level. Food index and ethanol production were the next variables in importance after military expenditures, confirming that across the Americas, food security is a major factor to make biofuel policies, as is the capacity the country has to produce ethanol.

Rural employment is no doubt an important determinant for biofuel policies. Proof of that is the adoption of biofuel policies in different countries under job creation acts, as explained in this paper. However, with low job creation, mainly in Central America and the Caribbean area, in which most countries of the Americas are, the concern over the years included in this research project could have focused on mitigating problems in other areas of concern to improve countries' conditions, including nationwide employment. This could result in this variable not being significant in the model presented here. Also, as explained in Chapter II, countries in Central America and the Caribbean have a comparative advantage in refining and producing ethanol that gave them the opportunity to not only produce this biofuel, but also to import from other countries, process, and export to the U.S., taking advantage of the BASIN initiative. This means that these countries have an incentive coming from outside their countries to produce ethanol and to adopt biofuel policies, which can result in these countries having a determinant to adopt biofuel policies not related to rural job creation, but at the same time it helps to address the problem. Under these terms, it is understandable that the rural employment variable turned out to be non-significant.

Oil production was also revealed as an important factor for biofuel policies, while oil reserve was not. This result might be influenced by the reality in the U.S. and Brazil, the largest ethanol producers in the world, which are also big oil producers. On the other hand, the region also has countries with some of the largest oil reserves in the world but do not produce ethanol, which might be responsible for the variable oil reserves as not significant in the model. An important condition to be considered in this point, and believed to have strong influence in this outcome, is that extracting oil from Venezuelan wells is considerably more expensive than extracting oils from other countries that have higher productions of petroleum-derived fuels because of depth and other geographical reasons. This, along with the refining process itself being comparatively more expensive and also due to its low level of purity, makes the oil from Venezuela to be a bad competitor against the same product coming from other countries. Therefore, making the variable oil reserve in this model not significant.

The results in this Chapter reveal that countries in the Americas highly rely on their economic situation for the adoption of biofuel polices. Although the former resulted in the variable with the highest significance level, it is also of major importance for countries in the Americas to take care of basic needs before adopting biofuel policies. This could, in fact, confirm the previous statement regarding economic conditions, since energy security and food security can be assumed with total confidence to be highly correlated.

CHAPTER VII. REFERENCES

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APPENDIX

Table A-1. Energy security risk score and ranking for 25 large energy using countries, in 2010

Country	Score	Large energy user group rank
Mexico	851	1
United Kingdom	878	2
Norway	940	3
New Zealand	941	4
Denmark	942	5
Australia	942	6
United States	964	7
OECD	968	
Canada	995	8
Germany	1006	9
Indonesia	1013	10
France	1028	11
India	1045	12
Poland	1061	13
China	1072	14
Russia	1098	15
South Africa	1100	16
Spain	1105	17
Japan	1119	18
Turkey	1154	19
Italy	1159	20
Brazil	1165	21
Netherlands	1239	22
South Korea	1361	23
Thailand	1680	24
Ukraine	2277	25

Table A-2. Estimation of yield elasticity in corn according to different authors, in United States. A table from Keney and Hertel, (2009)

Authors	Period of Time	Data/Estimation Notes	Elasticity	*t*-Statistic
Houck and Gallagher	1951-1971	Time series with calibrated non-linear trend	0.76	6.33
		Time series with calibrated non-linear trend (acreage control program variable)	0.62	6.32
		Times series with linear trend)	0.28	3.59
		Times series with linear trend (acreage control program variable)	0.24	3.11
Menz and Pardey	1951-1971	Time series with calibrated non-linear trend (acreage control program variable) from Houck and Gallagher	0.61	5.61
Choi and Helmberger	1964-1988	Time series of fertilizer demand and yield response to fertilizer joint estimation	0.27	2.8
Lyons and Thompson	1961-1973	Pooled time series (14 countries)	0.22	3.13

Note: *t*-statistic are for linear coefficient from original estimation inestead of elasticity for all the studies except for Lyons and Thompson. To Menz and Pardey study Houck and Gallagher´s equation was used to calculate elasticity.

Table A-3. Means and standard errors for variables used in the model

Variable	Mean	Standard error
Oilreservep	4.05e-07	9.23e-8
Arablep	0.32	0.03
GDP	1.07e12	2.39e11
Milexpen	7.65e11	2.30e11
Empl	13.94	0.82
Food index	95.94	1.36
Etprod	32.72	9.18
Oilprod	1261.07	179.04
Gas price	0.74	0.03

Table A-4. Correlation matrix between explanatory variables

Variables	Oilreservep	Arablep	GDP	Milexpen	Empl	Food index	Etprod	Oilprod	Gas price
Oilreservep	1.00								
Arablep	0.28	1.00							
GDP	-0.01	0.26	1.00						
Milexpen	-0.08	-0.17	-0.03	1.00					
Empl	-0.23	-0.33	-0.31	0.02	1.00				
Food index	0.13	-0.08	0.04	0.09	0.08	1.00			
Etprod	-0.06	0.12	0.75	-0.03	-0.13	0.06	1.00		
Oilprod	0.24	0.36	0.90	-0.04	-0.37	0.03	0.62	1.00	
Gas price	-0.24	0.03	-0.12	0.16	0.14	0.51	0.03	-0.25	1.00