Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Diploma Thesis

An Economic Analysis of the Impact of Biofuel Production on Food Prices in the United States of America

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Bc. Ghaith Hasan

Economics and Management

Thesis title

An Economic Analysis of the Impact of Biofuel Production on Food Prices in the United States of America

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Objectives of thesis

The aim of the thesis is to analyze the correlation between energy markets and agricultural commodity markets and the impact of biofuels on deepening this relationship, and the direct and indirect impact of the growth of biofuel production on the prices of agricultural basic food commodities and their volatility and to explain the potential contribution of biofuels to the development of the agricultural sector in the United States of America.

Methodology

The methodology of the thesis is to provide literature review about theoretical information on ethanol production policies in the United States of America and its efficiency. To measure the relationship between ethanol production and food prices during the period 2007-2017, econometric models will be used through using time series framework on ethanol and agricultural prices, stationarity and unit root, evaluate the interrelationship between the main variables by using Vector Error Correction (VECM). The regression analysis will determine the dependency and validity of the examined data.

The proposed extent of the thesis

60 – 70

Keywords

Ethanol, Renewable energy, Energy, Agricultural products, Food prices, Econometrics, United States of America.

Recommended information sources

A. J Benesi :The science of ethanol production, ASIN: B0006YEI4E

Estimating the Net Energy Balance of Corn Ethanol Hosein Shapouri, James A. Duffield, and Michael S. Graboski Agricultural Economics Report No. (AER721) 24 pp, July 1995 http://www.ers.usda.gov/media/926108/aer721.pdf

Jeremy Rifkin: The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World, ISBN : 978-0-2-230-3497-5

Expected date of thesis defence

2017/18 SS – FEM

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Prague on 22. 03. 2018

Declaration

I declare that the diploma thesis on the topic: "**An Economic Analysis of the Impact of Biofuel Production on Food Prices in the United States of America**" was written by me, by the help of specific literature and other sources which are included in the review of the used material, and by the help of consultations and advice with my supervisor **Assoc. Prof. Ing. Mansoor Maitah, Ph.D. et Ph.D.**

In Prague 22th of March 2018 Signature……………………..

Acknowledgment

I would like to give special thanks to the **Assoc. Prof. Ing. Mansoor Maitah, Ph.D. et Ph.D**. for his useful comments related to the writing of this thesis and for his professional behavior. Furthermore, I would like to dedicate this work to the soul of my beloved father who accompanied me every day, to my dear mother and my great brother, to my beloved Nour, many thanks to you all.

Ekonomická analýza dopadu výroby biopaliv na ceny potravin ve Spojených státech amerických

Souhrn

Není pochyb o tom, že výroba etanolu, jakožto zdroje obnovitelné energie, se za posledních deset let rapidně zvýšila. Ve Spojených státech amerických se objevil trend ke snížení závislosti na fosilních palivech díky očekávanému poklesu energetických zdrojů a škodlivým emisím, které významně ovlivňují globální klima a přispívají k globálnímu oteplování. Na jednu stranu, skleníkových plynů vznikajících z etanolu je o 60% méně ve srovnání s benzínem. Na druhou stranu, výroba etanolu ze zemědělských plodin představuje ekonomický problém, neboť zemědělské produkty jsou spíše určené k potravinářské spotřebě než energické, což vede k negativnímu dopadu na zemědělské trhy a ekonomickému konfliktu mezi palivem a potravinami. K analyzování vztahu mezi výrobou etanolu a cenami potravin na americkém trhu bude použito regresní modelování. V tomto ekonometrickém modelu se bude zkoumat vztah mezi rostoucí výrobou etanolu a cenami zemědělských komodit (kukuřice a pšenice) v období 1995-2017.

Klíčová slova: etanol, obnovitelná energie, energie, zemědělské produkty, ceny potravin, ekonometrie, Spojené státy americké.

An Economic Analysis of the Impact of Biofuel Production on Food Prices in the United States of America

Summary

The production of ethanol as a source of renewable energy has increased rapidly over the last ten years. In the United States of America, a growing movement has emerged to reduce the dependence on fossil fuel due to the decline in energy resources expected to occur. In addition to the harmful gas emissions which affect the global climate significantly and contribute the global warming. However, this increase of ethanol production as a source of energy has few pros and cons. On the one hand, the percentage of greenhouse gases resulting from the ethanol is 60% less when it is compared to gasoline. On the other hand, Ethanol production from crops poses an economic problem as agricultural products are often directed to food rather than to energy. This will lead to a negative impact on the agricultural markets and to a conflict between fuel and food. To analyze the relationship between ethanol production and food prices in U.S. market, a regression modeling will be used. In this econometric model, the relation between rising ethanol production and agricultural commodity prices (corn and wheat) will be examined in the period 1995-2017.

Keywords: ethanol, renewable energy, energy, agricultural products, food prices, econometrics, United States of America.

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1. Introduction

The close link between economic development and energy consumption is one of the essential characteristics of the modern world economy. Energy consumption - particularly fossil energy sources - has exceeded economic growth since the beginning of the second half of the 20th century. This high correlation has created several problems facing the future of development in the world; especially in relation to depletion of energy resources, environmental degradation, and imbalance due to the waste of production and consumption of fossil energy sources. This requires moving from an energy-based economy that is environmentally polluting to an economy that is based on renewable and environmental-friendly resources.

In this context, the biofuels are considered important renewable energy options to improve energy security and reduce environmental risks[1], in addition to redistributing energy rents to the agricultural sector. However, biofuel includes a range of threats to the natural resource base, the agrarian land as well as the food markets and its prices. There are also the potential environmental, economic and social costs of the expansion of biofuels production as an alternative source in the transport sector. During the period 2000-2007, biofuel production increased by more than three times, so that it covers about 2 percent of global fuel consumption for transport purposes.

Although the role of liquid biofuels for transportation is currently limited and its contribution to global energy supplies is modest, the demand for this energy source is increasing as a result of comprehensive programs to expand its use in the United States of America, the European Union, Brazil and other countries. The desire to reduce the fossil energy dependence of these large consumers will lead to increase the demand for agricultural food products, such as sugarcane, maize, and oilseeds to produce liquefied biofuels. This, in turn, will lead to upward pressure on food prices. Additionally, it will change in the nature of agricultural land allocation and consequent effects on water resources quality and quantity. Nevertheless, the potential positive impact on the agricultural employment and the economies of developing countries should not be overlooked. Hence, a careful assessment of the costs and benefits offered by this option in line with the orientation requirements for achieving sustainable development is required.

[1] ABENGOA [online]: "How Do Biofuels Affect Climate Change?" 2018. WWW: <http://www.theenergyofchange.com/biofuels-climate-change>

The importance of this subject feed into to the importance of the role played by energy in the global economy and the current trends towards the development of clean and renewable energy sources as alternatives to low energy sources. The issue of producing environment-friendly energy is one of the most critical aspects to achieve the sustainable development and the millennium development goals, also to make sure that the commitments of the Kyoto Protocol are met.[2]

Biofuel production directly depends on agricultural production and food security resources. That is why it is important to study the risks posed by the expansion of biofuel production and the opportunities it offers to reconcile energy and food issues in the world.

[2] Filho, W. [Online]: "International Journal of Environment and Sustainable." 2017. WWW: <http://www.inderscience.com/jhome.php?jcode=ijesd>

2. Research aims and methodology

2.1. Research aims

This research aims to:

- Analyze the dimensions of the energy problem associated with the existing energy model and the main factors driving the search for alternatives to the fossil energy sources in general and in the transport sector in particular.
- Explain of the status and the importance of biofuels as one of the energy sources of biomass in the energy market and the positive and negative economic, social and environmental impacts resulting from using this fuel as an alternative source of traditional energy sources in the transport sector.
- Analyze the policies to support the production and the use of biofuels and their economic feasibility, also to identify the objectives and motives behind these policies in the United States of America.
- Analyze the correlation between energy markets and agricultural commodity markets and the impact of biofuels on deepening this relationship, and the direct and indirect effects of the growth of biofuel production on the prices of agricultural essential food commodities and their volatility.
- Explain the potential contribution of biofuels to the development of the farm sector in the United States of America.

2.1.1 Hypotheses

In the light of the above, I propose the following research problem:

- How can the production of biofuels as alternative energy affect the agricultural development and the food prices in the United States of America?

For this key research problem, the following sub-questions can be asked:

- Does the world live a crisis of energy resources? What is its nature?
- What are the benefits of biofuels as a renewable energy source compared to conventional sources?
- How efficient is the biofuel produced in the United States of America in providing economically sustainable energy?

To answer these questions, I put forward the following assumptions:

- H1: The world is experiencing a multidimensional energy crisis as a result of the depletion of traditional sources and their environmental impacts.

- H2: The expansion of biofuel production and its consumption in the United States play limited roles in achieving energy security for its low economic and environmental efficiency.
- H3: Biofuels are a real contender for food production on water and land resources, they are negatively affecting the food prices in the USA markets.
- H4: There is a positive correlation between the ethanol production and the food prices.

In this research, I address the policy of biofuel production in the United States of America as one of the largest energy consumers in the world. The USA has been implementing and investing in the development of biofuels since the 70s of the last century. It has become the largest producers and consumers of biofuels currently. I have focused on the period between 1995 and 2017 as it is the period of the booming in biofuel production.

2.2. Methodology

This thesis starts by providing a literature review about theoretical information on biofuel and its global production and consumption. Then, information about policies in the United States of America and its efficiency will be offered. Next, I move to measure the relationship between ethanol production and food prices during the period 1995-2017, econometric models will be used using a time series framework on ethanol and agricultural prices “especially corn and wheat” as the primary source of ethanol production in the United States of America. Price index numbers will be used to calculate the changes in the prices of food commodities to indicate the difference in prices between periods. The regression analysis will determine the dependency and validity of the examined data.

3. Literature review

3.1. Liquid biofuels as fuel for transport

Liquid biofuels are the essential modern forms of biomass energy use. Its production depends on the conversion of several varieties of food crops, food grains, residues of agricultural activity and other biomass. Although biofuels are not a newcomer to the energy market, interests have been rapidly increased in ethanol in recent years as an alternative or complementary to petroleum fuels in the context of shifting towards clean and renewable energy sources.

3.1.1. Biofuel Essence

Biofuel is a combustible material; its production depends mainly on the direct or indirect conversion of plant or animal biomass. The primary sources of this type of energy are wood fuel, charcoal and plant products rich in starches, sugars, and oils, as well as organic waste resulting from the food industry.

1. **Types of biofuels:** There are many kinds of biofuels and the most important, widespread and used of these types are:

   A) Liquid biofuels: This type acquires the most attention among the types of biofuels and is divided into two main groups:

a) Alcoholic fuel: It is produced in several ways from plants rich in sugar and starches, especially cane sugar, sugar beet, corn and wheat, and the most important types:[3]

- **Bioethanol:** is the most popular and used type of biofuels, can be produced by sugar fermentation and can be used as a fuel substitute for gasoline in part or total.
- **Biobutanol:** produced by bacteria that convert sugar into butanol, and this type of biofuel is increasingly seen as an alternative fuel to oil because of its advantages compared with ethanol.
- **Methanol:** It is obtained from methane and can be used as an alternative to gasoline in a generic way, but it is considered as very toxic to humans.

b) Oil fuel: It is produced from a group of oily plants such as palm oil, sunflower, soybean, and others. Its production is being made by applying high pressure on the grain or using organic solvents. This type can be used in one of the following forms:[4]

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[3] Monassier, P. [online]: "Biofuels." 2011. WWW: <http://patrick.monassier.free.fr/energies/biocarburants/biocarburants.pdf > p. 5.

[4] Bryant, J & Love, J. "Biofuels and Bioenergy." 2017. p. 28. ISBN: 9781118350553.

- **Biodiesel:** It is produced from the chemical plant treatment by using ethanol or methanol, which can be used as diesel fuel easily and is characterized by sulfur-free, non-toxic and biodegradable, which makes it environmentally suitable.
- **Raw vegetable oil:** It can be used directly and emulsified with conventional fuel in the diesel engines, but it causes some technical problems due to the loss of its viscosity, which necessitates some modifications to the engines.

B) Bio gaseous fuel: It is represented in Methane, which is a biochemical produced by the organic fermentation of plant and animal organic wastes, such as waste from the food industry and agricultural waste. This gas can be used as a substitute for natural gas and as a fuel for different types of engines. Methane is characterized by its high energy efficiency compared to other biofuels, also, the simplicity of its production techniques. On the other hand, Methane cannot be stored; it must directly exploit when produced. However, the technical applications have been developed in the United States of America and Europe to process the Methane and transport it, but its exploitation remains weak compared to liquid biofuels.[5]

C) Solid biofuels: The traditional form of fuel that can be used in raw, the same as the direct burning of wood.

2. **Biofuel generations:** The types of biofuels used as fuel for transport are classified according to the possibility of availability at the present or future time. Accordingly, these species are divided into three generations. Generations of biofuels express Major developments in biofuel production regarding feedstock sources and the nature of the technology used and the potential environmental impacts of these species.

First generation fuel: The first generation indicates to the level of biofuels produced and used on a commercial scale in the current market. Its production depends on food products, protein, and oily crops by using relatively simple techniques such as fermentation. Currently, biofuel faces several criticisms over the diversion of food to fuel.[6] One of the most critical types of biofuels in the first generation is bioethanol, biodiesel, and biogasoline (bio-methane).

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[5] Monassier, P. [online]: "Biofuels." WWW: <http://patrick.monassier.free.fr/energies/biocarburants/biocarburants.pdf > p. 7.

[6] Arab Organization for Agricultural Development: "A Comparative Analytical Study of the Effects of Agricultural Crops on Biofuel Production." 2009. p. 12.

Second Generation Fuel: The second generation refers to the types of non-food feedstock substitutes, which are based on the conversion of the cellulose contained in the plants (wood, leaves, plant residues) to alcohol or gas by using specific technologies and technologies. This product is called Cellulose fuel, with the use of non-oil plants such as Jatropha, Jojoba, cane papyrus. The second generation is still at the development level with some applications, particularly in the aviation fuel sector. It includes several types: biohydrogen, bio-methanol, and wood diesel.

Third generation fuel: The production of third-generation biofuels depends on the use of (Microalgues), the third generation is more profitable than the previous generations from 30 to 100 times (from a theoretical point of view). In addition to the fact that what distinguishes it is that it does not compete with food and its production sources. In practice, the third generation is not economically viable and requires plankton cultivation with large amounts of fertilizers and chemical elements. The use of modified organisms is also a potential environmental hazard. This generation includes several types of bio propanol and biobutanol, which is the closest fuel to the benzene regarding its properties compared to ethanol.[7]

[7] Thomas F. McGowan, Michael L. Brown, William S. Bulpitt, James L. Walsh, Jr: "Biomass and Alternate Fuel Systems: An Engineering and Economic Guide." 2009. p. 17. ISBN 978-0-470-41028-8.

Table No 1: Table of biofuel characteristics

Fuel	Feedstock	Energy Density (Mega joules/Kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
		First Generation		
Bio alcohol	Starches from wheat, corn, sugar cane, molasses, potatoes, other fruits	By nature 30 34 36.6	By nature 1.91 N/A 2.37	
Biodiesel	Oils and fats including animal fats, vegetable oils, nut oils, hemp, and algae	37.8	2.85	
Green diesel	Made from hydrocracking oil and fat feedstock	48.1	3.4	Chemically identical to fossil fuel diesel
Vegetable Oil **Castor Oil** **Olive Oil** **Fat** **Sunflower Oil**	Unmodified or slightly modified	By nature 39.5 39 32 40	By nature 2.7 2.8 N/A 2.8	
Bio ethers	Dehydration of alcohols	N/A	N/A	These are additives to other fuels that increase performance and decrease

Fuel	Feedstock	Energy Density (Mega joules/Kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
Biogas	Methane made from waste crop material through anaerobic digestion or bacteria	55	2.74 (does not take into account the direct effect of methane, which is 23X more effective as a GHG than CO_2	Same properties as methane from fossil fuels
Solid biofuels **Wood** **Dried plants** **Bagasse** **Manure** **Seeds**	Everything from wood and sawdust to garbage, agricultural waste, manure	By nature 16-21 10-16 10 10-15 15	By nature 1.9 1.8 1.3 N/A N/A	This category includes a vast variety of materials. Manure has low CO_2 emissions, but high nitrate emissions.
		Second Generation		
Cellulosic ethanol	Usually made from wood, grass, or inedible parts of plants			
Fuel	Feedstock	Energy Density (Mega joules/Kilogram)	Greenhouse Gas CO_2(kg/kg)	Notes
Algae-based biofuels	Multiple different fuels made from algae	Can be used to produce any of the fuels above, as well as jet fuel	See specific fuels above	More expensive, but may yield more fuel per unit area.

Fuel	Feedstock	Energy Density (Mega joules/Kilogram)	Greenhouse Gas CO2(kg/kg)	Notes
Bio hydrogen	Made from algae breaking down water.	Hydrogen compressed to 700 times atmospheric pressure has an energy density of 123	Does not have any greenhouse effect.	Used in place of the hydrogen produced from fossil fuels
Methanol	Inedible plant matter	19.7	1.37	More toxic and less energy dense than ethanol
Dimethyl furan	Made from fructose found in fruits and some vegetables	33.7		Energy density close to that of gasoline. Toxic to respiratory tract and nervous system
Fischer-Tropsch Biodiesel	Waste from paper and pulp manufacturing	37.8	2.85	The process is just an elaborate chemical reaction that makes hydrocarbon from carbon monoxide and hydrogen

Source: Biofuel organization UK [online]: "Biofuel table." 2010. WWW: <http://biofuel.org.uk/types-of-biofuels.html>

3.1.2. The evolution of biofuels uses:

The use of biofuels in the transport sector has been known since the beginning of the last century, and this use is developed in several stages as follows[8]:

Phase 1: The purpose of biofuels as a fuel for transport is relatively old. There have been attempts of a run-off or total replacement of fossil fuels for the first time since the end of the 19th century. The German inventor Rudolf Diesel, the diesel-engine inventor, used peanut oil as fuel in a diesel engine. German engineer Nicholas August Otto also used the ethanol in his driver. Henry Ford also used it for the years 1903-1923.

This period witnessed efforts to market the bio-fuels through the exhibitions and car races. Ethanol use has expanded between the 1920s and 1950's, driven by the desire of reducing the energy dependency.

Phase 2: With the beginning of the seventies of the last century, the interest in biofuels returned, especially after the first oil shock of 1973 driven by strategic factors such as energy supplies and economic. This period has witnessed the launch of the most crucial biofuel production programs in the world, especially in Brazil and the United States of America. Brazil has been implementing an extensive program for the production of ethanol from cane, known as "the pro-alcohol scheme, this period noticed suspension of two types of subsidized fuel with tax evasion:

- A mix between 20% and 25% ethanol with gasoline.
- Ethanol 92% without petroleum materials (8% water).

In the United States of America, the researchers of the National Renewable Energy Laboratory (NREL), which launched since the early 1970s, has led the government to adopt the option to develop alternatives to fossil fuel. NREL has supported the use of a type of fuel known as (gasohol), which contains 10% ethanol and 90% benzene.

Also, the European countries, noticed same programs, such as the French program (Plancarburol), which was launched at the end of the 1970s under the national agenda for research and development on biofuels. In the same period, the case with the European Directive 85/356 / CEE on 5 December 1985, which specified the conditions of adding biofuels to gasoline.

By 1986, the counterbalance shock (low oil prices) and the pressure of multinational oil companies, led to a regression in the expansion of biofuel production.

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[8] World Health Organization. [Online]: “Fuel Technologies.” 2017. WWW: <http://www.who.int/sustainable-development/transport/strategies/fuel-technologie>

Phase 3: With the beginning of the third millennium and the combination of some factors, the global interest in biofuels as one of the most important solutions to face the challenges related to energy and the environment, which can be summarized in:

- High oil prices in light of decreasing the oil production and reserves in some regions of the world, in addition to the growing concern about the security of oil supplies.
-The increase in environmental pressures from climate change and global warming. These concerns were discussed through the Kyoto Protocol (1997), and the Millennium Goals of the Earth Summit in Johannesburg (2000), where the agreement was to reduce the volume of polluting emissions and expand the use of renewable energies especially biofuels as one of the essential types of it.

The EU countries have adopted the goal of using at least 5.75% of biofuels in the total fuel used, and the United States has adopted a significant program to expand biofuel use. This supportive context for the expansion of biofuel use has changed between 2005-2010, due to the decrease of surpluses in agricultural production and the increase of food prices, which reached its peak at the beginning of 2008 and caused social disorders in several regions of the world. Also, has warned concerns about the global food crisis, as well as interest in some environmental circles about the potential ecological impacts of industrial crops.

3.1.3. Major sources of biofuel production

The sources of biofuel production are numerous. At present, a group of agricultural food plots is being used for first-generation and non-food crops for the second and third generations.

A) Agricultural food crops:

It is divided into three groups; the main ones are cereal crops, sugar crops, and oilseeds:

a) Cereal crops: Cereals are the staple food crops of many countries of the world. However, maize and wheat are the main crops used to produce first-generation biofuels, and the main cereal crops used in biofuel production are:

- **Yellow maize:** maize is the primary grain crop on which ethanol is produced worldwide, especially in the United States of America and China. The proportion of users of the yellow corn crop for ethanol production in the United States increased from 3.7% in 1997 to 1% 41.9% in 2012. China also depends on maize production in ethanol production, the third largest ethanol producer in the world and the second producer of maize after the United States of America. The percentage of maize used to produce ethanol in China was about 9.89% in 2017, at the global level. The size used from maize in the production of Ethanol increased from 162 million tons in 2007 to 233 million tons in 2017 or almost two-thirds of world production, which amounted to 671 million tons during the same year.[9]

- **Wheat:** Wheat is the main crop of ethanol production in the EU. About 39% of ethanol is produced by grain. The most critical European ethanol producers from grain are:

  France relies on wheat for the production of ethanol based on wheat in the production of about 20% of its production of ethanol, and France is the first European Union and the fifth country worldwide in the production of ethanol as well as the fifth country in the production of wheat globally.

  Germany is the second largest producer of ethanol in the European Union. It produces about half of its ethanol production by using wheat. On the other hand, ryegrass considers the second source of ethanol production in the European Union, Germany relies on ryegrass to produce about 50% of its ethanol production.

  Spain is the third largest producer of ethanol in the European Union and relies on wheat to produce half of its ethanol production.

- **Barley:** Barley is also a primary source of ethanol production in the European Union. Spain relies on cereal to produce about 30% of its ethanol production. Barley production in the global ethanol production reached 39 million tons, about 30% of world production of 128 million tons in 2007, and the volume used reached 41 million tons of the total output estimated at 141 million tons during 2013.[10]

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[9] USDA [online]: "Feed Grains: Yearbook Tables." 2017. WWW: <http://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables.aspx>

[10] USDA [online]: "Feed Grains: Yearbook Tables." 2017. WWW: < https://www.ers.usda.gov/data-products/feed-grains-database/feed-grains-yearbook-tables/>

Table No 2: The main sources of ethanol production from cereals and sugar crops in the world (2007)

	Ethanol production Billion liters	Total production Million Tons	Medium productivity Ton-ha	Total area Million hectares
Wheat	205	602	2.8	215
Rice	271	630	4.2	150
Corn	284	711	4.9	145
Broom-Corn	22	59	1.3	45
sugar cane	91	1,300	65	20
Cassava	39	219	12	19
Sugar beet	27	248	46	5.4

Source: Macqueen, D. [online]: "Prospects and Challenges of Biofuels in Asia: Policy Implications." 2007. WWW: <http://pub.iges.or.jp/modules/envirolib/upload/1565/attach/07_chapter5.pdf>

b) Sugar crops: Sugar crops are considered as one of the primary sources of ethanol production, especially sugar cane and sugar beets, which are considered the most profitable and easier to process compared to grain crops.

- **Sugarcane:** Sugarcane is the most important sugar crop in the production of ethanol. Brazil relies mainly on its production of sugar cane, which is the world's largest producer of sugar. It uses about half of its sugar cane production in ethanol. India is also the second country after Brazil to produce sugar cane also on this crop in the production of ethanol, the fourth country in the world in the production of ethanol and the proportion of users of cane sugar for the production of ethanol in India, 10.14% in 34/2006.[11]

- **Sugar Beet:** Sugar beet is one of the most important crops used to produce ethanol in the European Union, particularly in France, which is the world's first producer. The percentage of beet production for ethanol production in France was 52.4% in 2007[12] at

[11] Mustafa H.: Economic Study for the Production of Biofuels. 15th Conference of Agricultural Economists. Cairo. 2007.
[12] Mustafa H.: Economic Study for the Production of Biofuels. 15th Conference of Agricultural Economists. Cairo. 2007.

the global level, the rate of sugar beet used in ethanol production was 29% of world production in 2010.

c) Oilseeds: Oil crops are one of the leading sources of biodiesel production, especially rapeseed, soybeans and palm oil.

- **Soybean:** Soybean is an essential oil crop and is also the primary source of biodiesel production in Argentina, the United States, Brazil, and Canada. The United States relies on soybeans for biodiesel production and is the world's fourth-largest biodiesel producer and first in soybean production. Total US biodiesel production rose from 7 million gallons in 1997 to 561 million gallons in 2009, an increase of more than 80 times compared to 1997, and 1 percent of soybeans for biodiesel production in the United States of America 1 23.65% of the volume of 1 in 2012.[13]
- **Rapeseeds:** The rapeseeds oil represents the main source on which the EU depends on biodiesel production, and the user ratio of canola to biodiesel production in the EU has increased from 1,024 million tons per year to 7,840 tons in 2012.

  In addition to the European Union, China also depends on the rapeseeds on biodiesel production, and it is considered as the fifth country in the world in producing biodiesel and the world's first in the production of canola.

- **Palm oil:** It is produced in tropical regions and is one of the most important sources of vegetable oil production in the world, and it represents the primary source first in the production of rapeseed in many developing countries Especially in Malaysia and Indonesia the first and the second product of palm oil in the world respectively. Palm oil is the highest productivity among oilseeds with a yield of up to 6000 liters per hectare and the most efficient in the production of biodiesel by about 230 liters of seeds.

B) Non-food crops: Known as energy crops and can be used to produce first and second-generation biofuels, noting that some of these items face difficulties in processing and conversion, the most important of these crops are the following:

a) Jatropha plant: Jatropha is a dendritic plant growing in warm areas it can be used to combat desertification, and it is characterized by its low consumption of water and no need for any fertilization. Jatropha is an oily plant with high oil content in seeds

[13] USDA [online]: "Oil Crops." 2017. WWW: <http://www.ers.usda.gov/publications/ocs-oil-crops-outlook/ocs-14l.aspx>

which amounts to 40% of seed size,[14] and the yield of one shear after two years of the transplant reaches 4 kg, and it increases with the age of the tree to 18 kilograms. Jatropha productivity varies across regions according to production conditions ranging from 0,4 to 12 tons per hectare per year, while oilseed productivity ranged between 304.8 and 1524 liters per ton, which has prompted many investors to pay attention to this plant as a source of biofuel production in Africa.

b) Jojoba plant: Jojoba is a dandelion plant that grows in the desert areas and is characterized by its ability to withstand the harsh environmental conditions such as high temperatures, drought and salinity, and the new shrubs needs irrigation duration of two years. Jojoba is one of the oily plants in which the oil content reaches between 45% and 65%, and its productivity reaches 400 kg per hectare in the early years of planting and can increase productivity to 2 tons per hectare after several years and up to 4 tons per hectare in some developed species.

c) Kenaf plant: Kenaf is a multi-use plant characterized by high biomass and rapid growth, known as a good source of pulp, it can be used to produce bioethanol because of the high cellulose in its legs which accounts for 74% of plant weight. Its seeds are also used to create biodiesel, where the percentage of oil in seeds reaches 26.4%, and the productivity of the Kenaf ranged between 6 and 10 tons per hectare annually.

C) Algae: Algae are microorganisms that are fast growing making it the candidate to be the source of biomass highest productivity of biofuels from the third generation, where productivity exceeds the productivity of wild oil plants between 30 and 100 times[15] according to some studies. Algae are characterized by no competition for food on farmland and no deforestation, as is the case with energy crops, and they give the most cost-effective if the growth is in the center of the concentration of carbon dioxide in it to about 13%.[16]

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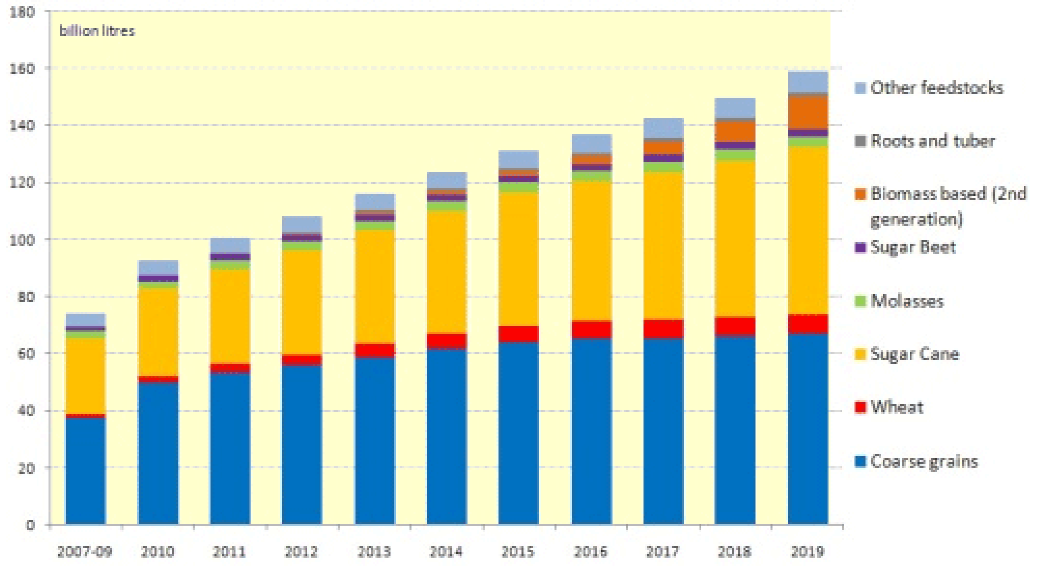
[14] M. Sawadogo et al., Modeling and evaluation of the economic performance of logistics of an oil mill: case of Jatropha in Burkina Faso, 4th biofuels conference and Bioenergy, International Institute for Water and Environmental Engineering, 21 to 23 November 2013.

[15] National Renewable Energy Laboratory [online]: "a look back at the US department of energy's program: Biofuel from algae." 2016. WWW: <https://www.eere.energy.gov/biomass/pdfs/biodiesel-from-algae.pdf>

[16] National Renewable Energy Laboratory [online]: "a look back at the US department of energy's program: Biofuel from algae." 2016. WWW: <https://www.eere.energy.gov/biomass/pdfs/biodiesel-from-algae.pdf>

Figure No 1: Global ethanol production by feedstock from 2007-2019



Source: The Crop Site [online]: "Biofuel Production – Greater shares of commodities used." 2010. WWW: <http://www.thecropsite.com/articles/1781/biofuel-production-greater-shares-of-commodities-used>

3.1.4. The use of biofuels in the transport sector:

The biomass is used for multiple energy purposes such as electricity generation, thermal applications and the most common use as a transport fuel,[17] where transportation use two main types of biofuels are ethanol and biodiesel, as well as biogas, marginally. Biofuels are mobilized in the transportation sector according to various forms depending on fuel characteristics and usage objectives, and in this latter area, multiple utilizations can be distinguished of biofuels according to their characteristics. In addition to the use of biofuels as an alternative to oil fuel, there are some species used to improve the combustion process in oil fuel or to reduce some harmful emissions from conventional fuel combustion. Also, to improve some of the physical and chemical properties of this fuel in order to enhance burn efficiency, and here biofuels will be used as auxiliary fuel or as an additive according to the quantities used. These use help to reduce the use of specific harmful industrial ingredients and additives to traditional fuels or stop their use utterly such as lead, sulfur, aromatic compounds and others.

[17] World Health Organization [online]: "Fuel Technologies." 2018. WWW: <http://www.who.int/sustainable-development/transport/strategies/fuel>

A) Ethanol uses: Ethanol is the most widely used biofuels in the transportation sector, accounting for 80% of the world's total biofuels. It is used as an alternative fuel in gasoline-powered cars according to one of the following two factors:[18]

- Wet ethanol (aqueous): is produced by distillation from biomass fermentation and contains 96% ethanol of the total mass produced. It is used as a fuel to blend it with up to 15% gasoline.

- Dry ethanol (anhydrous): pure alcohol obtained after the removal of water from wet ethanol and the proportion of ethanol is not less than 99.7%. Dry ethanol can be used as an alternative fuel for gasoline with some modifications to the engine.[19]

a) Ethanol Filling Patterns: Ethanol fuel is marketed in various commercial forms across different countries used for this type of fuel, and one of the most widely used species:

- E10 fuel is known as gasohol, and it is a mixture of ethanol and gasoline containing ethanol at 10%;

- E85 fuel is known as flexible fuel technology and is a mixture that contains 85% ethanol, and it is the mixture used in the United States and requires some changes in the engine;

-E22 is a blend of 20% to 24% ethanol. This mixture is used in Brazil and also requires some changes in the engines;

E100 fuel is fuel from ethanol (100% ethanol) and is used in Brazil and needs an engine adjustment.

b) Ethanol as an additive to conventional fuels: In addition to being used as an alternative fuel, ethanol is used as an additive to petroleum fuels to improve some of its properties in the place of the previously used petroleum and industrial additives. It is used as an additive directly or after conversion to Methyl tert-butyl ether (MTBE) as an additive Oxygen for conventional fuel. It increases the oxygen content of the fuel to

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[18] IEA, [online]: “Technology roadmap: Biofuels for transport.” 2011. WWW: <http://www.iea.org/publications/freepublications/publication/technology-roadmap-biofuels-for-transport.html>

[19] Abbott, P.C., C. Hurt, and W.E. Tyner. [online]: “What's Driving Food Prices?” 2008. WWW: <https://www1.eere.energy.gov/bioenergy/pdfs/farm_foundation_whats_driving_food_prices.pdf>

improve combustion, making the emission of certain harmful substances very low. The use of ethanol as an additive to gasoline in the United States of America has begun to replace lead. Especially after the prohibition of the use of lead due to the fact that it has an adverse effect on health. As well as the oil-based MTBE that has been prevented from being used for adverse impact on the environment, especially on groundwater.[20]

c) Technical advantages and disadvantages of ethanol use:

The use of ethanol as an alternative to petroleum fuels has a range of advantages and disadvantages.

Advantages: One of the most critical benefits of ethanol is:

1. Ethanol contains oxygen, so it is better than gasoline, especially in areas where oxygen is low as high-altitude areas;

2. Ethanol has a high self-ignition point compared to gasoline and diesel, which helps to store it relatively well;

3. Ethanol contributes to stopping using some harmful fuel additives such as lead oxide and aromatic hydrocarbon which cause cancer.

Disadvantages: The main disadvantages of using ethanol are:

- Increase the rates of volatile organic matter leading to higher ozone levels in the air.

- Increased corrosion rates of metals both in motor vehicles and in fuel transport and distribution systems.

- Ethanol susceptibility to water absorption, which increases the possibility of separation from benzene when combined.[21]

- The need to make significant changes in the engines if the use of ethanol is by more than 85%.

[20] FAO [online]: “Agro fuels and Food Security, High Level Expert Group on Food Security and nutrition.” 2013. p. 36 WWW:<http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/>
[21] Conserve Energy Future [Online]: “What is Ethanol Fuel.” 2016. WWW:< https://www.conserve-energy-future.com/ethanol-fuel.php>

B) Biodiesel use:

Biodiesel derived from vegetable oils is second regarding its use as a fuel for transport. It uses an alternative to diesel oil in raw form or after processing to become EHV with specifications similar to the specifications of the oil diesel, enabling the use of the current distribution network efficiently, and the most important types are:

- Raw vegetable oil: which is not chemically treated is used in some diesel engines in limited quantities as agricultural tractor engines after purifying it and removing some fatty components that make it difficult to use in cold areas.

- Ester vegetable oil: The commercial form of biodiesel characterized by the convergence of its characteristics with the essential attributes of diesel oil, which can be replaced by raw vegetable oil easily and without obstacles compared to crude vegetable oil.

a) Biodiesel filling patterns: Like ethanol, biodiesel can be used as a substitute fuel for diesel oil or as an auxiliary fuel

- The filling of biodiesel as fuel at low rates: Biodiesel is mixed with diesel oil up to a maximum of 20% of the size, and the most important varieties in the style of packing are:[22]

-B5, which is a blended mixture of diesel oil and 5% biodiesel, it can be used directly in diesel engines without any modifications. This form is widely used as fuel for trucks in many EU countries such as France and Italy.

- H BIO is a mixture used in public transportation in Brazil. Biodiesel accounts for 18% of the total volume.

- B20 is a blend of 20% biodiesel, widely used in the United States as fuel for trucks.

- B 30 Biodiesel is used as an auxiliary fuel with a fuel mixture of up to 30%, which is mainly used in public transport for its role in improving urban air quality in EU countries after several experiments conducted by the Technical Union of the Automobile and Bicycle Industry. Another mix of public transport in Brazilian cities was tested, with 32% biodiesel, 8% ethanol, and 60% biodiesel.

[22] International Energy Agency. [online]: “Technology Roadmap – Biofuels for Transport.” 2017. p. 108 – 109. WWW: < https://www.iea.org/etp/tracking2017/transportbiofuels/>

- B100: Biodiesel can be used as fuel oil (100% biodiesel) with some changes to fuel systems and engines. This mode is used as fuel for trucks in Europe, especially in Germany, Austria, and Sweden, which are interested in promoting the use of this type of fuel.

b) Biodiesel as an addition to the fuel oil:

Biodiesel is also used as an additive to the oil fuel, which increases the lubrication capacity of diesel oil when adding biodiesel, which reduces the erosion of equipment by a large percentage as well as reducing the sulfur content in conventional fuel and improving its combustion by raising the oxygen content of the fuel.[23]

Table No 3: Basic characteristics of some vegetable oils compared to petroleum diesel

	Thermal value (k kg)	**Density (kg m3)**	**Viscosity (mm2 tha)**	**Cetane number**
Diesel	43,350	815	4.3	47.0
Sunflower oil	39,525	919	58.5	37.1
Cotton seed oil	39,648	912	50.1	48.1
Soybean oil	39,623	914	65.4	37.0
Corn oil	37,825	915	46.3	37.6
Rapeseed oil	37,620	914	39.2	37.6

Source: Amin, A. [online]: "Study on the characteristics of palm oil–biodiesel–diesel fuel blend." 2017. <https://www.sciencedirect.com/science/article/pii/S1110062117300119?via%3Dihub>

[23] Amerigreen Energy [online]: "Biodiesel FAQs." 2015.WWW: <http://www.amerigreen.com/education-article/biofuels-faqs>

c) Technical advantages and disadvantages of using biodiesel:

The use of biodiesel as an alternative to petroleum fuels also has a range of advantages and disadvantages, the most important of which are[24]:

Advantages: The main benefits of using biodiesel are:

- Maintaining the performance of the engines so that the performance of biodiesel reaches the same efficiency as diesel oil.

- The use of biodiesel as an additive improves the sliding properties of diesel oil, which is reflected in the performance of engines.

- Non-containment of vegetable oils on sulfur makes them more environmentally friendly compared to diesel oil and the combination of them together reduces the size of the emission of suspended particles.

- Increase the oxygen level in diesel, which improves the combustion process.[25]

Disadvantages:

- High viscosity in vegetable oils requires modification of the engine, but this problem is overcome by using the ester vegetable oil.

- The use of vegetable oils causes an increase in nitrogen oxide emissions.

C) Use of biogas:

Biogas is used as fuel after purification according to the standards of natural gas to become similar to natural gas (GNV). However, its use remains very modest compared to liquid fuel, although it is one of the cleanest. In transportation reduces carbon monoxide emissions by about 80%, NOx, and 40% and suspended particles by 90%. Like other types of biofuels, it requires substantial engine modifications due to compressed self-ignition, which limits its current expansion nowadays.

[24] Food Grease Trappers. [Online]: "Green Oil: How Biodiesel Is Made." 2018.WWW: <https://foodgreasetrappers.com/2015/03/green-oil-how-biodiesel-is-made/>

[25] Mosnier, A. P. Havlik, H. Valin, J. Baker, B. Murray, S. Feng, M. Obersteiner, B. McCarl, S. Rose, and U. Schneider: "The Net Global Effects of Alternative U.S. Biofuel Mandates: Fossil Fuel Displacement, Indirect Land Use Change, and the Role of Agricultural Productivity Growth. Energy Policy" 2013. p. 602-614.

3.2. The biofuel markets

Liquid biofuels represent the only form of renewable energy currently used in the transport sector, which is known for continuous growth despite the significant decline in the volume of investments directed to this sector. The growth in demand has led to the emergence of many producing countries, which work to increase the value of biofuel production to cover the internal application of their local markets. On the other hand, the new players in the biofuel production field are expecting to anticipate of the expansion of international trade outside the traditional production and consumption areas. Also unifying efforts to create an organized global market in line with Brazil's initiative within the framework of the World Trade Organization to solve the barriers facing the international trade of biofuel.

3.2.1. The leading producers and consumers of biofuels:

The production and consumption of biofuels are distributed to a growing number of countries in the world, but the bulk of production and consumption is concentrated in a limited group of countries, which can be divided into two categories:

A) Mature markets

Three central regions currently dominate the global biofuel market Brazil, the United States of America and the European Union.

- Brazil: Brazil is the historical leader in the production and use of biofuels in the transportation sector. It is the second largest producer of bio-ethanol based on sugarcane and the world's first producer of sugarcane.

Bioethanol as fuel in Brazil has been noticed three stages:

- The period of growth between 1975 and 1990, which saw a significant expansion in the production and consumption of ethanol by the government program “Proalcool.”[26]

- The period of recession between 1990 and the beginning of the present century due to the oil shock and the decline in oil prices.

- The stage of the return of growth from the beginning of the century to the present, due to the rise in oil prices in conjunction with the expansion of the production sector of

[26] Biofuel [online]: "National Fuel Alcohol Program (Proalcool)." 2010. WWW: <http://biofuel.org.uk/National-Fuel-Alcohol-Program.html>

flexible fuel cars (FFV). This stage has had a significant role in the growth of consumption of bio-ethanol as fuel, as the number of units produced from this type of cars from about 490 thousand vehicles in 2003 to approximately 1.39 million in 2006 to represent more than 50% of vehicles produced in Brazil.[27]

Ethanol consumption reached 12 million tons in 2005 and exceeded 25 billion liters in 2011, where 60% ethanol is mixed in the form of a mixture of gasoline and 40% as a pure fuel. The volume covers 40% of gasoline consumption and 15% of total transport fuel in Brazil.

In addition to covering domestic consumption, Brazil aims to export mainly to Japan, whereas the Japanese government is considering the possibility of mixing 3 to 10 percent ethanol with gasoline, as well as the US and European markets where ethanol imports are subject to customs duties.

As well as Brazil is one of the leaders in the bio-ethanol industry, it is also interested in bio-diesel, where a national program has been launched to use the bio-diesel to reduce imports of oil diesel and develop the production areas of raw materials mainly in soybeans. Brazil is one of the world's largest producers of soybeans[28], with Argentina and the United States of America. At the same time, Brazil is the most significant producer of soy oil, and the Brazilian oil company "Petrobras" expects that the production of biodiesel will cover 25% of Brazilian diesel oil imports.[29]

- **United States of America:**

The United States is the largest producer of ethanol globally after exceeded Brazil since 2007, by more than 51 billion liters in 2011, yet the consumption of ethanol remains modest of the total use of transport fuel, covering only 1.5% of the volume of fuel consumed in Road transport. The Energy Act of 2005 gave significant weight to biofuels as part of US energy policy to reduce oil dependency in the Middle East through compulsory mixing and development of second-generation biofuels.

[27] OECD, [Online]: "A brief History of Brazilian Proalcool Program." 2012. WWW: <https://www.oecd.org/sti/biotech/Giacomazzi.pdf>

[28] Energy Information Administration. [Online]: "Today in Energy." 2016. WWW: <https://www.eia.gov/todayinenergy/detail.php?id=30372>

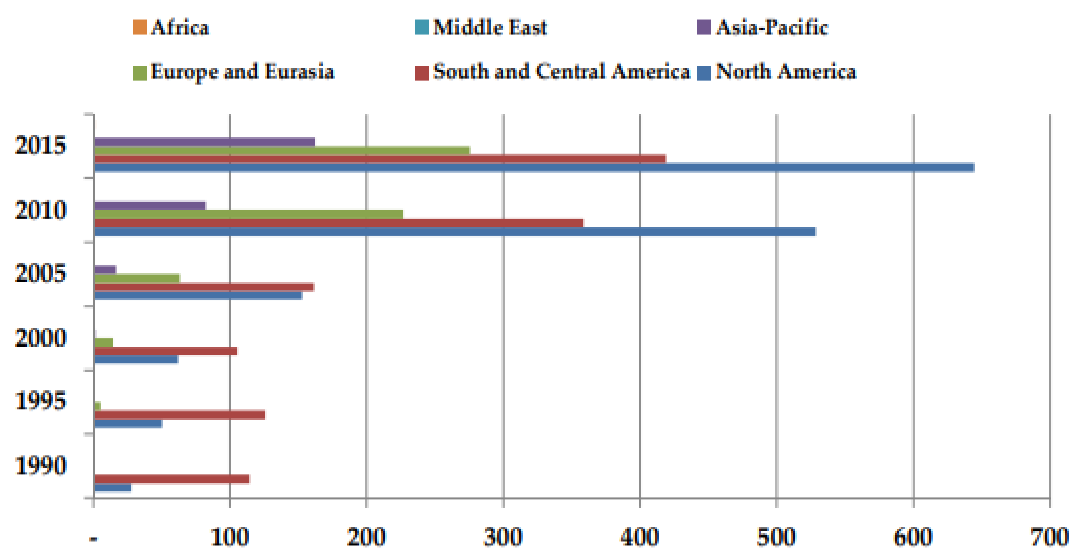
[29] IFP [online]: "energies Novellas." 2016. WWW: < https://www.ifpenergiesnouvelles.com/Research-themes/New-energies/Biofuel-production/(language)/eng-GB>

Ethanol production in the USA has been growing steadily since the late 1990s, with the number of production units rising from 50 units in 17 states producing 1.4 billion gallons by the end of 1998 to 211 units with 14.7 billion gallons in 28 states providing 13.1 billion gallons in 2012 As well as other groups under construction. Currently, 90% of the gasoline consumed in the United States contains up to 10% ethanol.[30]

Like Brazil, the United States of America has begun to pay attention to bio-diesel as an alternative to diesel oil in heavy transport. The biodiesel industry is a modern industry in the United States of America where it started at the beginning of the century.

The United States is the second largest producer and consumer of bio-diesel after the European Union. Also, the United States is trying to reach the first place after completion of projects to raise production capacity to 5 million tons per year.[31]

Figure No 2: Global biofuel production by region (thousand barrels per day).



Source: MDPI, [Online]: "Global Biofuels at the Crossroads." 2017. WWW: <http://www.mdpi.com/2077-0472/7/4/32/htm>

[30] Urbanchuk, J. [Online]: "Contribution of the ethanol industry to the economy of the United states." 2008. WWW: <https://www1.eere.energy.gov/bioenergy/pdfs/2007_ethanol_economic_contribution.pdf>
[31] OSTA, [Online]: "Background information on biofuel: Ethanol production in USA." 2008. WWW: <http://ostaustria.org/bridges-magazine/volume-17-april-28-2008/item/3044-background-information-on-biofuels-ethanol-production-in-the-united-states>

- European Union:

The European Union knows a bit of a delay compared to the US and Brazil in the production and use of bio-ethanol due to the control of diesel on the European transport sector. The European ethanol production concentrated in Germany, Spain, Sweden, and France.

The consumption was 2.7 million tons of equivalent oil in 2009 then raised to 1.7 million tons of same oil in 2010, noting that the EU allows mixing bioethanol with gasoline without lead within 5% without reference to distribution stations.[32] Unlike the United States of America and Brazil, EU countries except Sweden do not use ethanol directly but are used in the form of MTBE, which is the result of the interaction of ethanol with isobutene, an oil derivative. This European peculiarity comes from meeting European transport fuel standards.

In contrast to its ethanol status, the European Union dominates the biodiesel market. Biodiesel is the number one biofuel in the EU, given the nature of the European fuel market, dominated by diesel, which accounts for 60% of spent fuel. This fact explains the significant growth of bio-diesel Compared to ethanol, biodiesel accounts for 77% of European consumed biofuels compared to 21% of ethanol, 1.3% of crude vegetable oil and 0.4% of biogas. Noting that the EU allows mixing biodiesel with diesel oil within 7% without reference to the distribution stations.[33]

B**) Emerging markets:** Many countries are moving in light of the fluctuations in oil prices and the rise to adopt programs for the development of the use of biofuels, especially those countries that have significant agricultural potentials.

- China: China's interest in biofuels has emerged at the beginning of this century in line with the tremendous economic growth and the growth in oil imports, which accounted for 55% of Chinese consumption in 2010 and are expected to exceed 75% in the 2030 horizon. This prompted the Chinese government to adopt the renewable energy option by choosing the renewable energy policy in 2000, which aims to cover 15% of renewable energy consumption by the year 2020. This policy included encouraging the

[32] European Commission [Online]: “Biofuel Overview.” 2017. WWW: <https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels>

[33] European Commission [Online]: “Thematic Research Summary, Biofuels.” 2014. WWW: <https://setis.ec.europa.eu/energy-research/sites/default/files/library/ERKC_%20TRS_Biofuels.pdf>

production of biofuels through the 10th Five-Year Plan (2001-2005) to protect the environment, which included the introduction of ethanol as fuel for transport, and mainly depends on maize, with the fact that China is the second largest producer of maize. China is currently the largest producer of ethanol in Asia and the third largest producer in the world 3.950 million liters of oil equivalent in 2018 with a target of 6.4 million tons of oil equivalent in 2020.[34]

In addition to the critical ethanol on the Chinese biofuel market, China produces biodiesel in modest quantities of 100,000 tons per year compared with diesel consumption of 70 million tons per year. Under the renewable energy development plan, China is seeking to produce 2.3 billion liters of biodiesel by the year 2020.

In order to promote the production of biofuels, the Chinese government has invested 70.6 million US dollars in the establishment of biofuel production units, in addition to providing support to producers of $ 294 million and help for sales by $ 201.9 per ton in 2008, as well as tax exemptions for producers.[35]

Given the specific targets and their possible implications for food security conditions, the Chinese government revised its biofuel policy in 2006 by deciding to use non-food crops to produce ethanol and to use Jatropha for biodiesel production, to be constructed on the non-farm land.

- India: Along the lines of China, India is experiencing significant economic growth, to respond to the increase in energy consumption, which oil imports cover a large part of it, about 75% of consumption covered by oil imports in 2010.

In addition to that, the increase in polluting emissions, especially the transport sector which grows at an average of 9% annually and consumes more than 50% of the oil. India has adopted the European emission standards that encourage the use of clean fuels[36], so India started an ethanol development program in 2002 which clarify that the

[34] Yoonhee M, [online]: "Growing Interest for Ethanol Brightens Prospects." 2017. WWW: <https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_10-20-2017.pdf>

[35] IEA [Online]: "sustainable production of second generation biofuels: potential and perspectives in major economies and developing countries." 2010, p. 124. WWW: <https://www.iea.org/publications/freepublications/publication/second_generation_biofuels.pdf.>

[36] FAO [online]: "agro fuels and food security." 2008. WWW: <https://www.researchgate.net/profile/Philip_Mcmichael/publication/265669477_Agro-fuels_food_security_and_the_metabolic_rift/links/570f86bf08ae1c8b7c5448a4/Agro-fuels-food-security-and-the-metabolic-rift.pdf>

ethanol will be produced from sugar cane production as India is the second largest sugar cane producer in the world after Brazil. Production reached 1.08 billion liters of ethanol and 240,000 liters of biodiesel in 2008. India has begun to use a 5% ethanol mix with gasoline since the year 2007. In 2009, the Government of India decided to meet the target of mobilizing 20% of ethanol and biodiesel in spent fuel in 2017[37] under the National Biofuel Policy, which is based on four primary objectives:

- Meeting the energy needs of the population, especially in rural areas, with development in these areas and the provision of jobs.

- Responding to international requirements for reducing greenhouse gas emissions through the use of biofuels that meet environmental standards.

- Production of bio-fuel depending on non-food raw materials produced on marginal or unfit land, while avoiding any competition between food production and fuel production.

- Development of local biomass resources and promotion of biofuel production from developed generations.[38]

The production capacity of ethanol is about 500,000 tons per year. However, the volume of production is influenced by the change in sugar cane production surplus in the domestic market which is related to climatic conditions (2.3 million tons in 2007 and less than 1 million tons in 2009). That pushed the Indian government to use E10 for ethanol and B2 for biodiesel.[39]

Argentina: Argentina is a rising producer of biofuels and the second largest producer in South America after Brazil with a production of 1.8 million tons in 2009, most of the output (85%) which is exported, making Argentina the world's largest exporter of biofuels. With the rapid growth of this sector, the US Department of Agriculture

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[37] IFP [online]: "Biofuels Worldwide." 2007. WWW: <http://www.ifpenergiesnouvelles.com/content/download/56045/1266567/version/6/file/IFP-Panorama07_07-Potentiel_biomasse_VA.pdf.>
[38] FAO [online]: "agro fuels and food security." 2008, WWW: <https://www.researchgate.net/profile/Philip_Mcmichael/publication/265669477_Agro-fuels_food_security_and_the_metabolic_rift/links/570f86bf08ae1c8b7c5448a4/Agro-fuels-food-security-and-the-metabolic-rift.pdf>
[39] IFP [online]: "Biofuels Worldwide." 2007. WWW: <http://www.ifpenergiesnouvelles.com/content/download/56045/1266567/version/6/file/IFP-Panorama07_07-Potentiel_biomasse_VA.pdf.>

forecasts that Argentina's exports will rise to 8 million tons in 2020, especially with the government incentives for biodiesel exports.

Concerning the growth of domestic demand after the adoption of B7 mix and its entry into use, where the market consumed about a quarter of the production in 2010, bringing domestic demand to over one-third of production in 2011.[40]

Argentina's biodiesel industry consists of two integrated branches. The first is the Argentine SMEs that supply the local market. The second branch includes the major international companies that direct their production to export to the US and European markets in the first place.

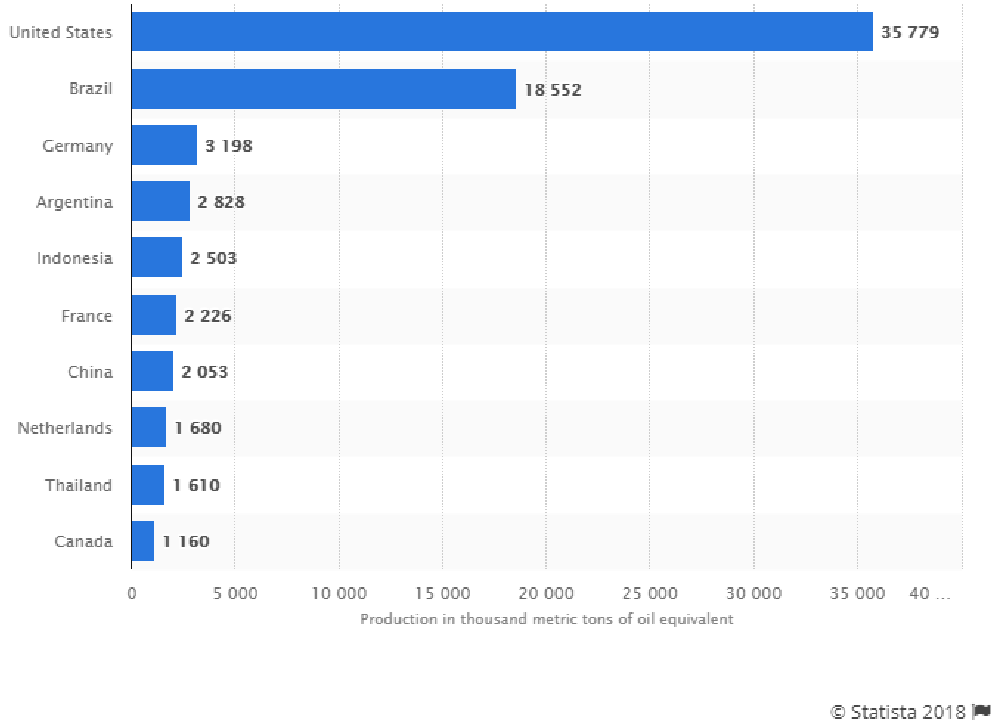
In the same format as biodiesel production, Argentina is moving towards the development of ethanol production driven by two main factors: the growth of maize production in savannah fields in the center of the country and China's significant investment in this field.

C) Other countries: Malaysia and Indonesia are the primary producers of palm oil and are developing biodiesel production as a factor for economic development through the development of the biodiesel export sector and primary feedstock mainly to the EU, as well as support for the domestic use of biodiesel.

[40] Guibert, M. & Cecilia, S. [online]: "Biofuels in Argentina: factors and challenges of the production of soy biodiesel." 2012. WWW: <http://dx.doi.org/10.1051/ocl.2012.0451.>

Figure No 3: Leading countries based on biofuel production in 2016

(in 1,000 metric tons of oil equivalent)



Source: Statista, [Online]: "Leading countries based on biofuel production in 2016." WWW: <https://www.statista.com/statistics/274168/biofuel-production-in-leading-countries-in-oil-equivalent/>

3.2.2. The production structure and costs of the biofuel industry:

Unlike petrol (gasoline and diesel) produced from refining oil through the distillation process. The methods of producing liquid biofuels vary according to the nature of the fuel and the materials used in its production as explained below:

A) Biodiesel Production:

a) Biodiesel production stages: The conversion of vegetable oils to bio-diesel gives fuel with a specification very close to the specification of diesel oil, and the conversion process is carried out in three necessary stages, preceded by an initial stage of preparation of the leading seeds as follows:

- Primary stage: Is the stage that precedes oil extraction, and it is represented in preparing seeds in three steps. The first step is to sort and clean seeds to get rid of plant residues as much as possible.

- The second step is to grind the seeds with the aim of cracking the fat cells to facilitate thermal conversion and extraction.

- The third step is heat treatment to reduce oil viscosity and to promote the retrieval of seeds.

- Oil extraction: Oil extraction is done in two ways:

1. Mechanical method: The pressure of the grain after grinding cold at a maximum temperature of 60 degrees Celsius or hot at a temperature between 80 and 120 degrees Celsius.

2. Using solvent extraction: Where the seeds are mixed with a solvent to get a mix contains 20% of oil and 80% of solvent, this product is then distilled to separate the oil from the solvent. This method is used to increase the amount of oil extracted compared to the mechanical process, but this method is usually used only in units whose production capacity exceeds 500 tons per day.

- Crude oil refining: At this stage, the unwanted ingredients are eliminated in the crude vegetable oil, which contains more than 4% of the fatty acids. That is by adding water or steam to isolate those components and then remove them by centrifugation in the first stage, and in the subsequent phase, the oil is purified from free fatty acids and soap resulting from the centrifugation.

- Mutual estrangement: During this phase, vegetable oil is converted into bio-diesel by processing oil using alcohol with a catalyst for reaction and heat, and this process produces biodiesel, a secondary product of glycerin, which is intended for use in some chemical industries.

b) Inputs and production costs: Biodiesel production requires a range of feedback and value across different stages, from raw material to final product.

- The production phase of the raw material: The cultivation of oilseeds just like other production processes needs to use a set of factors of production to obtain the output of oilseeds on the one hand and the remnants of its cultivation on the other side which can also be used for energy purposes.

- The factors of production are fixed factors such as land area allocated to agriculture, which is usually set during the production cycle, and variable production factors that vary according to production conditions such as pesticides, fertilizers, machinery costs and other production costs.

- The industrial stage: includes the extraction of crude vegetable oil and converting it into bio-diesel. The cost-effective of oil extraction from rapeseed is 40% in other words, producing 1 ton of oil requires 2.5 tons of oilseeds, and after crude oil refining, the esterification process is converted into diesel by mixing it with methanol with 100 kg for each ton of oil. This process produces 1000 tons of biodiesel and 100 kilograms of glycerin[41].

B) Bioethanol Industry:

a) Bioethanol production stages: The ethanol industry is undergoing a range of steps including:

- Preparation of raw materials: include the purification of starch or sugary raw materials and grinding to obtain a powder.

- Sugar extraction: It is by adding water to powdered sugar, while starchy crops require the conversion of starch into a pure sugar by adding enzymes and heating the mix to analyze starch and then extract sugar.

Extraction from sugar cane is more natural because it contains sugar in real images and with right concentration (about 20%).[42]

- Fermentation: The sugar solution is fermented to convert it into alcohol by adding yeast to the solution and controlling the heat to accelerate the reaction. The fermentation process gives ethanol and carbon dioxide, where the ethanol reaches 15%[43].

- Distillation: The fermentation mixture is distilled to separate the ethanol from other products. The distillation process gives alcohol containing 5% water[44], which is removed to get pure ethanol ready for direct use or for blending with petroleum fuel.

[41] Cavalett, O. & Junqueira, T [Online]: "Environmental and Economic Assessment of Bioethanol." 2011. WWW: <https://www.researchgate.net/figure/Processes-flowsheet-of-the-annexed-ethanol-sugar-and-bioelectricity-plant_fig1_228425031>
[42] Bioenergy Australia. [Online]: "How is ethanol made." 2016. WWW: <http://biofuelsassociation.com.au/biofuels/ethanol/how-is-ethanol-made/>
[43] ICM [Online]: "Ethanol production process." 2012. WWW: <http://www.icminc.com/innovation/ethanol/ethanol-production-process.html>
[44] Bioenergy Australia [Online]: "How is ethanol made." 2016. WWW: <http://biofuelsassociation.com.au/biofuels/ethanol/how-is-ethanol-made/>

b) Inputs and production costs: As for the production of raw materials used in the production of biodiesel, the creation of raw materials for the production of bio-ethanol requires direct inputs and auxiliary inputs that vary according to the content produced.

The industrial phase includes the conversion of sugar extracted from raw materials to ethanol, whose requirements vary according to the raw materials between starch and sugar crops.

For sugarcane used as raw material in Brazil, ethanol can be produced directly from canes or molasses (about 4.5% of production) or bagasse (about 25% of production), and the sugar yield of the reed reaches 12%.

Each ton of sugar cane produces 70 liters of ethanol, while one ton of molasses (which is directly fermented) yields 255 liters of ethanol on average.

Maize is the leading supplier of ethanol production in the United States. The cost of extracting starch from cereals is 69%, and each ton of corn gives an average of 410 liters of ethanol.[45]

Table No 4: Estimating the cost of ethanol production in the USA and Brazil (2012)

Unit: 1 $ per liter

	United States of America	**Brazil**
The cost of the raw material	0.23	0.14
The cost of conversion	0.12	0.04
Other costs	0.05	0.02
Income of secondary products	(0.11)	(0.11)
Cost of producing 1 liter	0.29	0.19

Source: Ballerini, D. “Biofuels: Meeting the energy and environmental challenges of the transportation secto.” 2012. p 314 & 316 ISBN: 9782710809838. Own table.

[45] Mustafa, B. & Balat, H [Online]: “Recent trends in global production and utilization of bio-ethanol fuel.” p. 61-62. <https://www.sciencedirect.com/science/article/pii/S0306261909000919>

C) Economic Interaction of Biofuel Production Activity: Biofuel production is linked to several sectors of economic activity, which include many productive activities on which biofuel production depends on the provision of inputs. As well as industries directly or indirectly dependent on this activity from the agricultural sector to the chemical, biotech, energy, transportation, distribution and other areas, in the form of background and forward linkages. That can give us a picture of the importance of biofuel production within the sectors of economic activity and its role in the development of various productive sectors in the economy.

It is noted that there is a multiplicity in the interrelationships of the biofuel production activity with its concentration in the agricultural sector. The available data on the contribution of biofuel production in the US economy shows that the agricultural sector ranks first in terms of relative importance. Especially, in the structure of inputs for biofuel production by contribution 84% of the inputs, then the energy and water sector, which contributes more than 6%, and the chemical industry sector by 5.4%.
These inputs account for more than 95% of the total inputs of biofuel production. This is consistent with the structure cost of production.

Table No 5: Relative importance of processed sectors for biofuel industry in the US economy for 2012

Sectors	**Inputs (million dollars)**	**Relative importance%**
Agricultural sector	33,110	84.49
Chemical industries	2,120	5.41
Energy and water	2,317	5.91
Industrial maintenance	346	0.88
Transportation	100	0.25
Public services	412	1.05
Other sectors	783	2.00
Total input	39,188	

Source: Urbanchuk, J. [Online]: “the contribution of the ethanol industry to the economy of the United States.” 2013. WWW: < http://www.ethanolrfa.org/wp-content/uploads/2015/09/Ethanol-Economic-Impact-for-2012.pdf>, Own table.

3.2.3. The development of the production and consumption of biofuels in the world

The production and use of biofuels has witnessed many fluctuations over the last two decades, but I will focus my studies on this period between "2007 - 2011" due to the real crises in the world economy, whether the global economic crisis in 2008 and the subsequent crises in food prices, which are the backbone of fuel production. This period represents an exceptional and significant period to see the real impact of disasters on the supply and demand of ethanol and biodiesel[46].

A) Trends in the development of biofuel production:

a) Evolution of Ethanol Production: Ethanol is the essential form of bioenergy and is increasingly used in the transportation sector as an alternative fuel or as a gasoline additive. Ethanol production is growing globally, with production increasing more than six times between 1991 and 2017, rising from about 16 billion years 1991 to more than 105 billion liters in 2011, most of this production is concentrated in the United States of America and Brazil about 75% of world production.

Table No 6: Evolution of global production of bio-ethanol 2007-2011

Unit: million liters

	2007	**2008**	**2009**	**2010**	**2011**
USA	29,944.19	35,746.35	44,354.32	48,469.73	51,142.03
Brazil	22,327.5	26,468.7	25,066.44	26,720.10	28,805.76
European Union	4,068.41	5,021	5,700.25	6,230.31	6,798.42
Canada	921.34	1,373.11	1,468.04	1,607.32	1,771.13
Argentine	227.53	210.31	321.08	377.51	288.32
World	**72,059.10**	**83,639.95**	**91,909.02**	**99,423.16**	**105,607.97**

Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012.WWW:<https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

[46] Lowa State University, [Online]: "Investment in Cellulosic Biofuel Refineries: Do Renewable" 2018. WWW: <http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1534&context=card_work>.

The United States is the world's largest producer of bioethanol since 2007 with the production of 30 billion liters,[47] equivalent to 42% of world production, and its production volume increased to 51 billion liters in 2011, equal to 48% of world production.

Brazil is the second largest country, benefiting from the fact that it is one of the largest producers of crops used in the production of biofuels. It ranks first in the world in the production of sugar cane with 16% of the world production and the second in the production of soybean by 26% and the third in the production of corn by7%, in addition to owning a significant forest wealth which is an essential source of bioenergy, as well as vast agricultural areas estimated at more than 90 million hectares. Brazilian production has grown steadily despite the decline in its contribution to world production by producing more than 22 billion liters in 2007, equivalent to 31% of world production, reaching 29 billion liters, equal to 27% of world production. The growth in output is mainly due to the increase in the yield of sugar cane and the increase in the percentage of sugar cane in the production of ethanol from 15% to 70% during the nineties of the last century to settle within 50% currently.

The EU is the world's third-largest producer of bioethanol with a contribution of 6% of world production and its production in 2011 was approximately 6.8 billion liters. The European production depends mainly on the wheat yield of about 50% of the production in the most important producing countries, which are: France, Spain, Poland, Germany, and Sweden.

At the same time, ethanol production is expected to overgrow in Asia, especially in China, whose consumption is increasing rapidly.

In India, which supports the biofuel industry, production is expected to reach 3.6 billion liters in 2018. As well as Thailand, which aims to reduce reliance on oil imports and raise the share of ethanol in fuel consumption of gasoline type from 2% in 2008 to about 12% in 2018, bringing the production to 1.8 billion liters.[48]

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[47] USDA. [Online]: "Charts of Note." 2018. WWW: <https://www.ers.usda.gov/data-products/charts-of-note/charts-of-note/?topicId=14>

[48] OECD & FAO. [Online]: "Agricultural outlook 2008 – 2017." 2017. WWW: < http://www.oecd.org/trade/agricultural-trade/40715381.pdf>

b) Development of biodiesel production: Biodiesel production proliferated between 1991 and 2017, with production volume increasing from 11 million liters to more than 23.5 billion liters. Production is concentrated in the European Union, the world's largest producer of biofuels and the United States, Brazil, and Argentina.

EU production was about 11 billion liters in 2011, equivalent to 46% of world production. Most European production comes from Germany, which is the largest producer and consumer of biodiesel in Europe, producing about half of European production. Biodiesel production in Europe relies on rapeseed oil and benefits from the EU's Common Agricultural Policy (CAP), which aims to reduce the surplus in food production to maintain price levels and encourage non-food crops, including energy crops.

The United States of America is the world's second-largest producer with nearly 3 billion liters representing 13% of the world's total production. In addition to the growth of the production of the most important producers, production is increasing in other parts of the world, especially East and Southeast Asia in China, Singapore and Indonesia, which are increasing the area of palm growing from 1.5 million hectares to 7 million hectares of the palm fields specialized to biodiesel production, which benefits from a subsidy of $ 100 million and in turn reduced the subsidies for oil fuel which was abolished entirely in 2005 to make the biofuel industry economically competitive.

Production began on a commercial scale in 2006 with a production level of 600 million liters per year in 2007 to reach 3 billion liters in 2017.

In Malaysia, the second largest palm oil producer in the world aims to reach 10% of the world's biodiesel production. Commercial production began in 2006 and production reached 360 million liters in 2007. Production is expected to grow 10% annually to 1.1 billion liters within ten years.

Table No 7: Evolution of global production of biodiesel, 2007-2011

Unit: million liters

	2007	**2008**	**2009**	**2010**	**2011**
USA	1,497.06	231,072	1,649.03	953.04	2,961.06
Brazil	319.98	952.63	1,293.40	2,405.01	2,469.95
European Union	6,492.05	8,063.56	9,567.55	9,919.63	10,845.98
Canada	97.46	140.97	253.30	314.84	332.19
Argentine	459.09	1,400	1,150	2,178	2,375.84
World	**10,950.28**	**15,819.17**	**17,179.09**	**19,825.72**	**23,578.57**

Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

B) Development of biofuel consumption:

a) Evolution of ethanol consumption: Ethanol consumption is growing significantly, but its contribution remains modest in total fuel consumption in the transport sector, accounting for only about 5% of global gasoline consumption. Global use increased from about 71 billion liters in 2007 to more than 106 billion liters in 2011 at an average annual growth rate of 10.7% during the period 2007-2011. It can be noted that the volume of consumption in 2011 exceeded the size of production and was covered by the use of reserve stocks, the increase in demand is due to the increase in mixing rates in some countries and the introduction of compulsory mixing into other countries.[49]

[49] Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf> p. 9.

Table No 8: Evolution of global consumption of bioethanol 2007-2011

Unit: million liters

	2007	**2008**	**2009**	**2010**	**2011**
USA	31,620.65	39,196.21	46,523.22	48,269.73	52,810.92
Brazil	18,758.96	21,312.84	21,828.96	24,625.59	25,119.33
European Union	5,011	6,698	7,080.36	7,779.98	9,310.85
Canada	1,107.57	1,443.41	1,429.20	1,718.50	2,281.94
Argentine	142	130	224.16	399.93	367.97
World	**70,980.04**	**83,377.51**	**92,932.01**	**99,152.15**	**106,628.93**

Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

Gasoline is dominating on the consumption of transport fuels in the United States of America, where it controls about 85%[50] of the total liquid fuel consumption, making it naturally the world's largest consumer of bioethanol. Its consumption reached 49.5% of total global consumption in 2011; the USA is known to have a continuous growth rate exceeding the global average of 13.7%. The United States had a deficit in consumption coverage of domestic production of 3% in 2011. The same was the case with the EU, the third largest consumer in the world, which had a 16.75% growth in consumption. Statistics show the deterioration of the balance of energy, where the deficit is known to increase from 23% of domestic production in 2007 to 37% in 2011. This situation is also known by Canada, where the percentage of dependency is 23% of its domestic production. Brazil is the second largest consumer of bio-ethanol worldwide, with 23% of the world's total bio-ethanol consumption falling in line with its share of global production.

[50] The Organization of Arab Petroleum Exporting Countries (OAPEC): "the growth of demand for petroleum products in major markets and its impact on member countries." 2014. p. 3.

Table No 9: Evolution of the percentage of consumption of bioethanol from domestic production, 2007-2011

	2007	**2008**	**2009**	**2010**	**2011**
USA	106%	110%	105%	100%	103%
Brazil	84%	80%	87%	92%	87%
European Union	123%	133%	124%	125%	137%
Canada	120%	105%	97%	107%	129%
Argentine	62%	62%	70%	97%	95%

Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

b) Evolution of biodiesel consumption: Global consumption of biodiesel has more than doubled between 2007 and 2011 at an average annual growth rate of 21.88% during the same period and is growing faster than ethanol consumption. Despite this rapid growth, however, the contribution of biodiesel remains marginal in total diesel consumption worldwide, contributing 1.5% of total world consumption.

Table No 10: Evolution of global consumption of biodiesel, 2007-2011

Unit: million liters

	2007	**2008**	**2009**	**2010**	**2011**
USA	1,056	1,196.8	862.4	668.8	2,323.2
Brazil	319.975	952.631	1,293.404	2,405.013	2,469.948
European Union	6,874.99	9,199.76	11,296.51	11,910.42	13,000.39
Canada	97.461	140.792	187.67	278.941	367.767
Argentine	0	0	209.749	532.211	540.455
World	**10,004.41**	**13,788.31**	**16,442.54**	**18,710.76**	**22,080.57**

Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

The EU is the world's leading biodiesel consumer because it traditionally relies on diesel, which accounts for two-thirds of the European fuel market. The EU accounts for about 60% of global consumption, and in 2011 it consumed more than 13 billion liters.

As with ethanol, The European Union's tariff on consumption of biodiesel rose from 6% in 2007 to 20% in 2011, while the United States recorded a surplus exceeding 20%. The growth of Brazil's consumption, which has moved from about 3% of global consumption in 2007 to 11% in 2011, has also been observed with self-sufficiency over the 2007-2011 period.

Table No 11: Evolution of the percentage of Biodiesel Consumption from Domestic Production 2007-2011

	2007	**2008**	**2009**	**2010**	**2011**
USA	%71	%50	%52	%70	%78
Brazil	%100	%100	%100	%100	%100
European Union	%106	%114	%118	%120	%120
Canada	%100	%100	%74	%89	%111
Argentine	%0	%0	%18	%24	%23

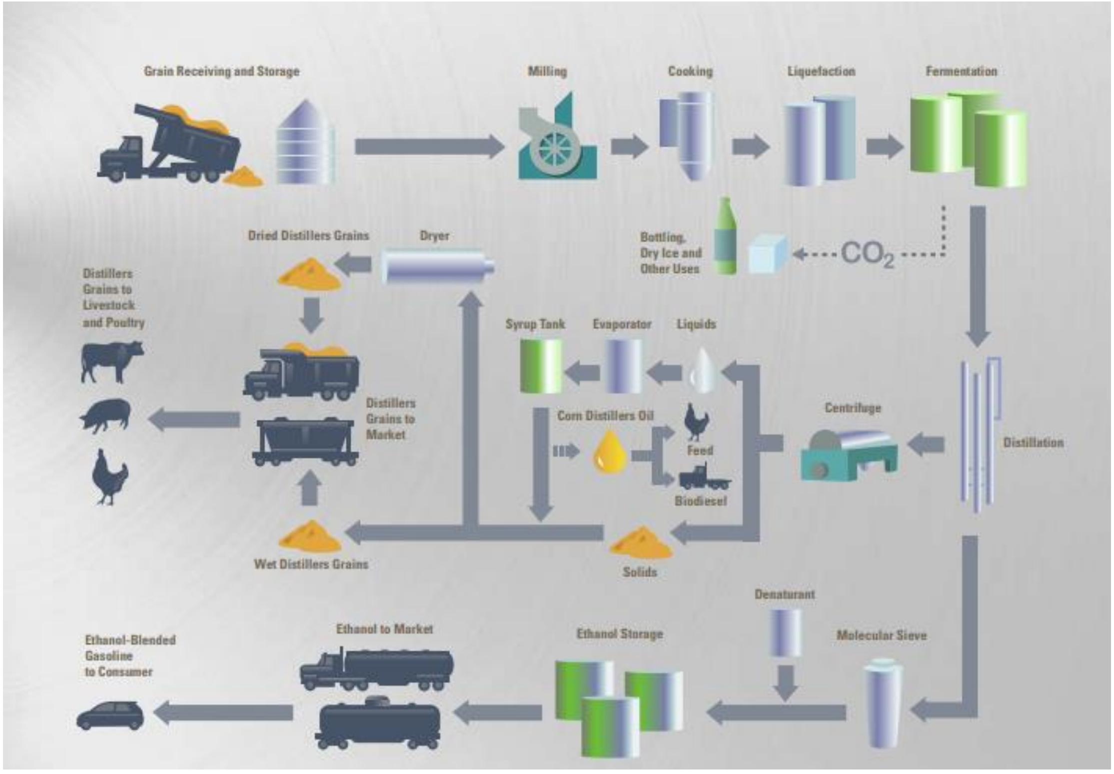
Source: Hanne, H. [Online]: "The production and consumption markets and the prices of biofuels in the European Union and the world." 2012. WWW: <https://www.economie.gouv.fr/files/files/directions_services/dgccrf/documentation/dgccrf_eco/english/DGCCRF_eco09_biofuels.pdf>, own table.

4. Practical part

As long as ethanol is concerned, the modern use of ethanol came many years after its simple beginning which was used first as motor fuel and dates back to the days of Henry Ford's Model and farm stills. However, modern processes are used by biorefineries to convert feedstocks into high-octane ethanol and many other essential co-products. The two methods of wet and dry milling are used to make fuel ethanol. A high percentage of 90 percent of the ethanol produced comes mainly from the operation of dry milling, while the rest comes from wet, milling. In the process of dry milling goes through many steps. First, all the grain kernel is ground into "meal" which is slurred after that with water forming a "mash." This mash is cooked, cooled and then transferred to fermenters. Next, yeast is added to trigger the conversion of sugar into alcohol. Then comes the step of separating the resulting "beer" from the remaining "stillage." The distillation and dehydration of the ethanol follow. Moreover, then it is blended with 2 percent of denaturant like gasoline to make it undrinkable. At this step, it is ready for shipment. As a result, the co-products become distillers' grains and corn oil.

However, the process of wet milling in United States of America goes through somehow different steps. First, the grain is soaked to separate it into its necessary components. Then, grinders are used to process the slurry and consequently separate the corn germ. The other remaining ingredients, such as gluten, starch, and fiber are further divided. Ethanol is produced by fermenting the extra glycogen by using a process similar to the dry mill process.

Figure No. 4: Dry mill ethanol process

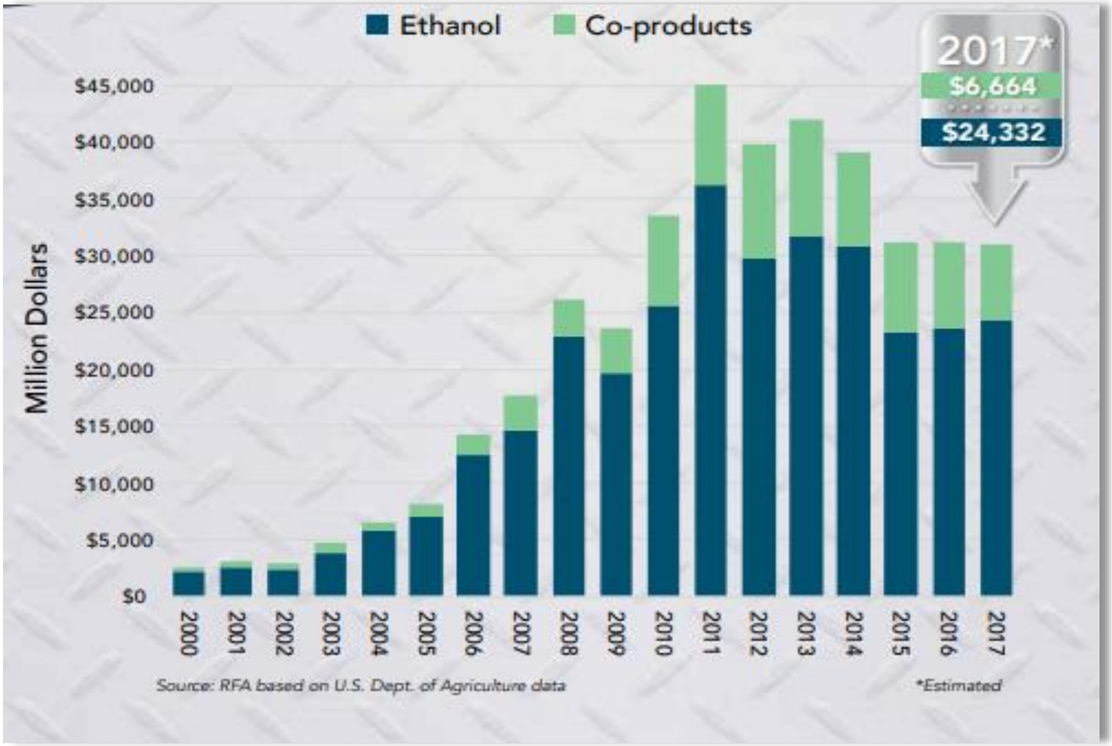


Source: Renewable Fuels Association, [Online]: “Ethanol strong, 2018 Ethanol industry outlook.” 2018. WWW: <http://www.ethanolresponse.com/wp-content/uploads/2018/02/2018-RFA-Ethanol-Industry-Outlook.pdf>

Ethanol also had its economic impact. Rural America, for instance, continued facing financial difficulties and challenges on many levels in 2017. According to Creighton University, many economic sides were dramatically affected like loans volumes in the Midwest region, hiring, retail sales and land values. The farm sector also bears some consequences like historically high grain stocks, decade-low commodity prices and rising input costs which, all together, badly affected bottom lines.

However, ethanol biorefineries played an essential role in making some balance. They offered a kind of lifeline in communities across the Heartland. For example, they helped in stabilizing commodity markets and stemming further economic losses. Thus, the growth in ethanol production continues bringing more investments, offering many job opportunities and improving solve many other economic problems.

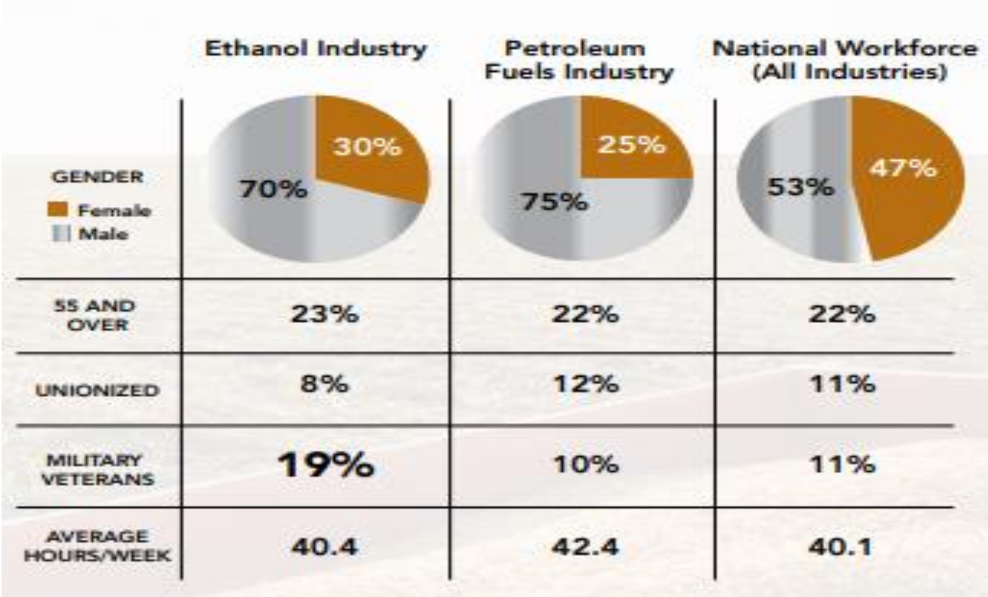
Figure No 5: Gross value of U.S. Ethanol industry output



Source: Renewable Fuels Association, [Online]: "Ethanol strong, 2018 Ethanol industry outlook." 2018. WWW: <http://www.ethanolresponse.com/wp-content/uploads/2018/02/2018-RFA-Ethanol-Industry-Outlook.pdf>

As a result, the production of 15.8 billion gallons of ethanol in 2017 gave jobs for 71.906 American workers. The ethanol industry also helped supporting thousands of induced jobs in many sectors of the economy. Moreover, it contributed to the national Gross Domestic Product and created billions in household income. Also, producers paid billions in taxes and spent billions on inputs, raw materials, and some other services. Practically speaking, surveys showed the contentment of workers in the ethanol production with their jobs on all levels. About 19 percent of the employees in this field are veteran of the U.S. military shedding light on their patriotism and American pride through.

Figure No 6: Ethanol industry workforce demographics



Source: Energy.Gov [Online]: “U.S. Energy and Employment Report.” 2017. WWW: <https://www.energy.gov/sites/prod/files/2017/01/f34/2017%20US%20Energy%20and%20Jobs%20Report_0.pdf>

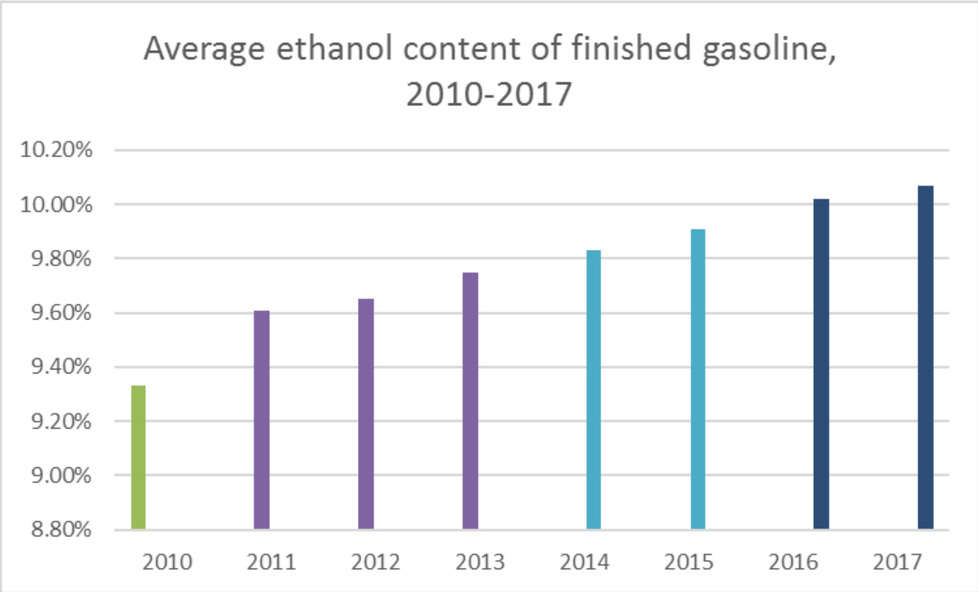
The revolution of the nation's fuel market came as a result of the emergence of ethanol as a significant ethanol component. As a result, as ethanol is blended into gasoline all around the states, domestic fuel supplies are extended ad consumer prices are lower.

The so-called fictional "blend wall" was exceeded by the blend rate in 2017 when ethanol accounted for a percentage of more than 10 of the U.S.A gasoline pool. It has been stated that Minnesota, for example, led the nation with an average content of ethanol near 13 percent. However, came in second of a close percentage. Well, this apparently goes against the myth in an industry that ethanol should have a limit of 9.7 percent of the gasoline pool.

It has also been noticed nationally that ethanol consumption has significantly risen between the years 2000 and 2017 from 1.4 billion gallons to 14.4 billion gallons. A similar noticeable increase has been registered in gasoline blend stock consumption. Thus, it can be vividly understood why many in the oil industry go against any further growth in renewables.

Keeping gasoline consumption in check and lowering fuel prices for American families are both results of increased ethanol use. Moreover, it is clear that ethanol will continue to bring positive change for consumers since the evolution of transportation sector continues.

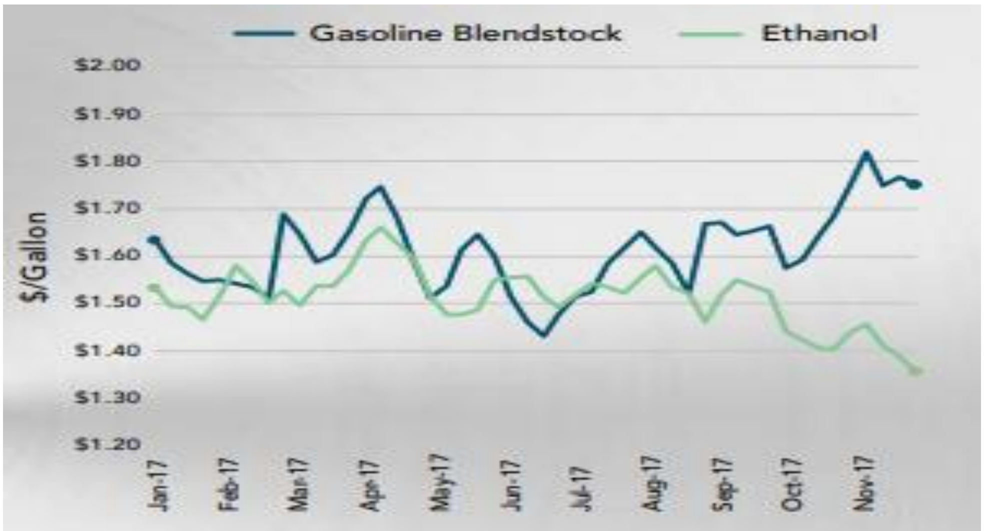
Figure No 7: Average ethanol content of finished gasoline 2010-2017



Source: U.S. Energy Information Administration and RFA data. 2017. own graph

It is also important to shed light on the advantage of ethanol's octane. Because automakers manufacture more useful engine technologies, the need for octane fuels continues to grow, and manufacturers delivered their message asking for more octane! However, sales of premium gasoline increased in 2017, but the problem is that traditional petroleum-based octane boosters are in short supply and considered expensive.

Figure No 8: Comparison of 2017 weekly gasoline and ethanol futures prices



Source: Renewable Fuels Association, [Online]: "Ethanol strong, 2018 Ethanol industry outlook." 2018. WWW: <http://www.ethanolresponse.com/wp-content/uploads/2018/02/2018-RFA-Ethanol-Industry-Outlook.pdf>

However, ethanol is a clean and affordable resource of octane which is ready to deliver with a blending octane rating 114. Refiners have replaced hydrocarbon, which was used in the past as a source for octane, with ethanol for many reasons the most important of which are the expensive process of increasing octane from hydrocarbon and the intensive need of energy for it on one hand, and the availability of ethanol and the useful properties of its octane on the other side. An even brighter future is expected for ethanol's role as a clean and affordable source of octane.

Having all the advantages mentioned above resulted in the emergence of what is called international ethanol trade as a global force. In 2017, it was America's ethanol industry that exerted itself as a worldwide force registering a high record in exporting ethanol. Thus, the united states were a top producer, consumer and exporter of ethanol in 2017. The top two markets were Brazil and Canada. Unfortunately, this export declined in some markets like China and Brazil due to some barriers. As long as ethanol's by-products are concerned, distiller's grains and other co-products form essential components of the global animal feed market and prominent contributors to the industry's bottom line. Thus, ethanol helps in creating both high-protein animal feed and fuel. America's ethanol producers stand ready to meet the increasing international demands for protein and caloric energy[51].

Since the focus is on fuel and renewables, it is essential to talk about The Renewable Fuel Standard (RFS) which has been the single most successful clean fuels policy in the united states helping in many ways like offering jobs, reducing the imports of oil and lowering gasoline prices, in addition to many other helpful things. It started in 2005 and was expanded in 2007.

4.1. Policy to support ethanol production in the United States of America:

Since the 1970s, the United States government has worked on a set of stimulus measures to help the domestic biofuel industry (Ethanol in particular) and make it competitive by using various means of support.

4.1.1. The importance of biofuel production in the US economy:

Biofuel production is linked to many sectors of economic activity on which biofuel production depends on it to provide inputs directly or indirectly, such as the agricultural sector, the chemical industry sector, the biotechnology industry sector, the energy sector, transport and distribution services sector, and other sectors.

These sectoral linkages can give us a picture of the importance of biofuel production within sectors of economic activity and its role in developing interdependencies between different productive sectors of the economy.

It is noted that there is a multiplicity in the back-link relations of biofuel production with its concentration in the agricultural sector. The available data on the contribution of biofuel production in the US economy shows that the agricultural industry is ranked first in terms of the relative importance of the structure of inputs for the production of biofuels with a contribution of more than 84%, followed by the energy and water sector, which contributes more than 6%, and the chemical industry by 5.4%. These inputs represent more than 95% of the data of biofuel production, which is consistent with the structure of production costs where the cost of agricultural raw materials is the most critical elements of the cost of biofuel production by up to 80%.[52]

[51] RFA, [Online]: "Animal Feed Production Protein Power." 2017. WWW: <http://www.ethanolrfa.org/wp-content/uploads/2018/03/animal_feed1.pdf>

[52] Chen, X. and Khanna, M. [online]: "Food vs. Fuel: The Effect of Biofuel Policies. American Journal of Agricultural Economics." 2012. p. 289-295. WWW: <https://academic.oup.com/ajae/article-abstract/95/2/289/69682?redirectedFrom=fulltext>

4.1.2. Objectives of the policy to support the production of biofuels:

The policy of promoting biofuel production in the United States of America, like many producers, aims to achieve a range of objectives which are mainly the following elements:

- Reduce the oil dependency of the American economy and contribute to the achievement of energy independence, especially for the transport sector which dominates by oil derivatives.
- To contribute to reducing the environmental impacts of energy consumption in the transport sector by reducing greenhouse gas emissions and improving the quality of the environment in urban areas.
- Contribute to the development of the agricultural sector and improve the income level of farmers by creating new outlets for production and stimulate demand for farm products.

4.1.3. The most important policy tools to support ethanol production:

The primary tools used to support biofuel production in the United States are:

A) Tax incentives:

The US government began using tax incentives with the 1978 Energy Tax Act, which provides an exemption for the combination of gasoline and ethanol (4-cent-per-gallon gasoline tax. In the same context, the government had introduced the Outcome Employment Law in 2004. This loan was extended by the Energy Policy Act of 2005 to include biodiesel oil worth $ 1 per gallon for diesel oil produced from agricultural raw materials and 50 cents for diesel produced from used fuels. As well as for biofuel production units with less than 60 million gallons per year, it gets benefits of tax cuts for the first 15 million gallons by 10 cents per gallon.

The volume tax loan for ethanol was amended in the Farmer's Act of 2008 down from 51 cents to 45 cents per gallon for corn-based ethanol, while a new tax loan of $ 1.01 per gallon of Cellulose ethanol was introduced.

Table No 12: Tax incentives to support ethanol in some US states

unit: US dollar per gallon

States	Tax cuts for the ethanol and gasoline mix	Tax cuts for ethanol production
Hawaii	Exemption from retail sales tax	
Idaho	Reduction to 10% of the gasoline tax	
Iowa	0.1	0.2
Minnesota	0.2	0.2
Missouri	0.2	0.2
North Carolina		Tax loan 30% of the cost of production facilities
Oregon	0.05	reduction 50% in real estate charges for ethanol production units in the state
Washington		Reduction 60% of the tax per mixes gallon

Source: U. S. Department of Energy, [Online]: “Alternative fuels data center.” 2016. WWW: < https://www.afdc.energy.gov/fuels/laws/ETH/US >, own table.

B) Quantitative objectives:

In addition to tax incentives, the United States has adopted mandatory mixing policy since 2005, and this trend was reinforced by the Energy and Security Independence Act (RFS1). This policy sets a quantitative goal of a compulsory mix-up of the US Renewable Fuel Petrol Standard by 7.5 billion gallons Ethanol until the year 2012, increasing this amount to 35 billion of ethanol gallons by the year 2017. For biodiesel, the standard for diesel oil was imposed at 500 million gallons in 2009, and this quantity had raised to 1 billion gallons starting in 2012.

In the year 2010, the Energy and Security Independence Act (RFS1) was modified by (RFS2) Act, which selected an ambitious goal represented in produce 36 billion gallons of ethanol in the year 2022, distributed to 15 billion gallons of first-generation fuel and 21 billion gallons of advanced biofuel.

C) Subsidies

On the other hand, the United States continues to support biofuel production through targeted grants to primarily develop the production of cellulosic fuel, where the Energy Security and Independence Act had allocated $ 500 million to encourage the use of biotechnology to produce competitive fuel from cellulosic materials under a research program between 2008 and 2015. As well as 200 million dollars dedicated to supporting ethanol fuel stations (E85), the US government also decided to subsidize the creation of cellulose ethanol production units worth $ 100 million in 2006, and this support rose to $ 400 million in 2008.

D) Customs fees:

In addition to domestic support measures, the US government works to protect domestic production against foreign competition through tariff barriers. Ethanol imports from non-FTA countries (ALENA) are subject to customs duties ranging between 1.9% and 2.5%, in addition to the state-imposed fee in addition to the MFN fee of $ 0.54 per gallon.

On the other hand, the United States distinguishes between imports of ethanol as fuel and ethanol for other uses. Additional charges for ethanol imports are imposed as fuel primarily targeting imports of ethanol from Brazil, which is a real competitor to US ethanol.

4.2. Evaluating the economic and environmental effects of biofuel subsidy policies in the United States of America

The efficiency of US policy for the production and use of biofuels can be analyzed from its contribution to achieving economic and environmental objectives, based on cost-benefit analysis.

4.2.1. Contribution to reducing energy dependence

Reducing energy dependence is one of the most critical drivers of biofuel production in the United States of America as a means of supporting domestic production of energy sources. However, ethanol production does not make a significant contribution to achieve this goal. Although US dependency ratios for oil imports has decreased and the volume of fuel imports went down, but the contribution of ethanol remains modest, where it did not exceed 7%, this decline is only affecting the oil used in the transport sector, while in other sectors it is due to the rise in domestic oil production.

The evolution of the contribution of ethanol to the reduction of oil imports destined for the production of equivalent gasoline from 3% in 2004 to more than 17% in 2017[53], this percentage is still below the level of achieving the independence of energy level which must not be less than 40% of the volume of imports, The share of the transport sector for petroleum products has declined by 11%, compared to 2011, which means that oil remains the dominant source of energy for the US transportation sector by more than 90%.

4.2.2. Contribution to employment and income:

The biofuel sector is one of the capital-intensive sectors of the economy, which means that its contribution to the creation of jobs will be lower compared to labor-intensive industries. The capital density of the biofuel sector in the US is characterized by the fact that the average employment opportunities available in the various activities related to this sector are directly and indirectly about 400,000 jobs per year during the period 2008-2016, mostly for the agriculture sector. The direct jobs are about 20% of the total job opportunities available which are low compared to some sectors similar to this sector regarding size Such as the dairy products sector, which provides more than 1.3 million jobs and the agricultural equipment production sector, which provides about 2 million jobs[54].

Despite the importance of the number of jobs offered by the biofuel sector, reliance on it as a motor for job creation may face difficulties due to several factors related to the nature of the sector. The limited production capacity and the level of mechanization may affect the levels of operation. Also, the vast production units achieve high levels of economies of scale while the number of workers per unit of output is lower. This can be seen by reducing the total number of jobs and the number of opportunities for the unit of output in this sector in the American economy, according to the following table, where the number of jobs decreases with the increase in the volume of production from one year to another.

[53] Renewable Fuels Association [Online]: “Ethanol strong, 2017 Ethanol industry outlook.” 2017. WWW: < http://www.ethanolrfa.org/wp-content/uploads/2017/02/Ethanol-Industry-Outlook-2017.pdf> p. 9.

[54] United States Department of Labor [Online]: “Employment Projections.” 2016. WWW: < https://www.bls.gov/emp/ep_table_207.htm>

Table No 13: Jobs generated from biofuel production in the US economy

Years	2013	2014	2015	2016	2017
Direct jobs	70,400	90,200	87,000	86,504	71,906
Indirect jobs	330,277	311,400	295,000	300,277	285,587
Total jobs	400,677	401,600	382,000	386,781	357,493

Source: Renewable Fuels Association, [Online]: "Ethanol strong, 2018 Ethanol industry outlook." 2018. WWW: <http://www.ethanolresponse.com/wp-content/uploads/2018/02/2018-RFA-Ethanol-Industry-Outlook.pdf>

4.2.3. Reducing greenhouse gas emissions:

The contribution of biofuels varies significantly in reducing greenhouse gas emissions, depending on the nature of the raw materials used and the methods of production. Based on the analysis of the role of biofuel life from raw material production to the use of the final product. Most studies conclude that biofuels achieve an emission reduction of between 20% and 60% compared to conventional fuels.[55]

By comparing levels of greenhouse gas emission reduction by the material used in biofuel production, ethanol produced from sugar cane is considered the highest fuel relative to other crops. For biofuel, soybean fuel is the most extensive contributor of crops used in production as shown in the following table, showing that raw materials used to produce biofuels in the United States of America and the European Union of corn and rapeseed are considered to be the least efficient in reducing emissions, while the crops produced Mainly in developing countries are considered the most efficient.

[55] Suzuki, D. [Online]: "What role can biofuels play in reducing greenhouse gas emissions?" 2016. WWW: <https://www.ecowatch.com/what-role-biofuels-play-reducing-greenhouse-gas-emissions-194663>

Table No 14: Reduction of greenhouse gas emissions by biofuel production materials

<table>
<tr><th>Sources of biofuel production</th><th>2016 ADEME estimates</th><th>OCDE estimates 2016</th></tr>
<tr><td>Ethanol from sugar beet</td><td>66%</td><td>%50 -%30</td></tr>
<tr><td>Ethanol from wheat</td><td>49%</td><td>%60 -%30</td></tr>
<tr><td>Ethanol from corn</td><td>56%</td><td>%50 -%20</td></tr>
<tr><td>Ethanol from sugar cane</td><td>72%</td><td>%90 -%70</td></tr>
<tr><td>Bio diesel from rapeseed</td><td>59%</td><td rowspan="4">%55 -%40</td></tr>
<tr><td>Biodiesel from sunflower</td><td>73%</td></tr>
<tr><td>Biodiesel from soybeans</td><td>77%</td></tr>
<tr><td>Biodiesel from palm oil</td><td>76%</td></tr>
</table>

Source: VTT, [Online]. “How to ensure greenhouse gas emission reductions by increasing the use of biofuels.” 2011. WWW: <http://www.vtt.fi/inf/julkaisut/muut/2011/Soimakallio_Koponen.pdf>. Own table.

A study of the environmental effects of biodiesel compared to petroleum diesel made by the US Environmental Protection Agency shows that the use of biodiesel reduces the emission of carbon monoxide by 50% and hydrocarbons by 70%, but increases the emission of nitrogen oxides by 10%.

4.3. The costs of biofuel support policies

The plans of biofuel subsidies are the essential factors in achieving production at current levels and reducing production costs, but the expansion of these policies raises the question of the costs involved.

4.3.1. Support costs in developed countries:

The biofuel sector is emerging as one of the targeted industries that rely heavily on government subsidy policies that depend on economically expensive tools. A study of the Global Institute for Sustainable Development under the Global Subsidies Initiative program shows the volume of transfers directed to biofuel subsidies in a group of OECD countries, which includes various forms of subsidies for this sector of tax incentives, tariffs and government subsidies for investment in development, research and compulsory mergers.

The total value of biofuel subsidies in 2006 in the United States was estimated at more than $ 6.3 billion and in the European Union $ 4.7 billion.

I note that this study confirms that support estimates are likely to be lower than the real value of government support due to the multiplicity of tools, forms of support and data confidentiality, which makes the exact identification of support values difficult, and the estimates did not take into account subsidies to the agricultural sector for production of raw materials.

Noting that 2006 was selected because the aid to various sectors of biofuel production has remained relatively constant in the selected countries

Table No 15: Estimated Total Support for Biofuels in Selected Countries

Unit: 1billion dollars

	Ethanol		**Biodiesel**		**Total biofuel subsidies**
	Total support	Average support USD / L	Total support	Average support USD / L	
United States of America	5.8	0.28	0.53	0.55	6.33
European Union	1.6	1	3.1	0.7	4.7
Canada	0.15	0.4	0.013	0.2	0.163
Australia	0.043	0.36	0.032	0.35	0.075

Source: Steenblik, R. [Online]: "Biofuels- At what cost?" 2007. WWW: < http://www.iisd.org/pdf/2007/biofuels_oecd_synthesis_report.pdf>. Own table.

The above table shows that the value of subsidies in the United States is the highest in absolute terms, while the average support for the unit produced in the EU is the highest among the subsidy values granted in different countries; which means that the level of EU biofuels subsidies is more extensive than what it is in The United States of America on the basis of the unit produced, as well as the modest value of total support does not reflect the relative importance of support for the fuel-producing unit.

4.3.2. The implications of subsidy policies on the biofuel industry in developing countries:

Strategies to support biofuel production in the United States have a multiple impacts on developing countries, beyond the impact on food security and economic competition.

A) Influence on the competitiveness of the biofuel sector:

The importance of the biofuel sector in the United States stems from contributing to the reduction of energy dependence and exploiting the surplus of agricultural production by the rules of the World Trade Organization.

The American biofuels industry is expensive and does not have the same competitive advantages as many developing countries such as Brazil and Argentina, for example, regarding production costs and economic and environmental profitability of raw materials, the adoption of support and protection policies is the key to addressing the competitiveness of this sector.

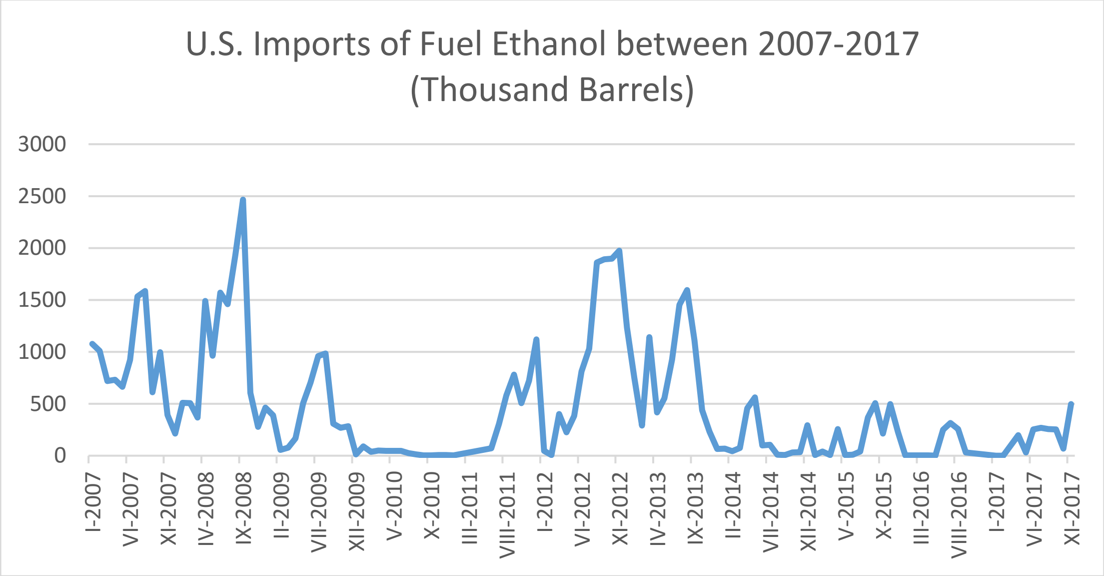
In view of the significant expansion of biofuel production, the US has used most of the agricultural areas, in addition to the high cost of labor and significant mechanization of the farm sector, which means higher energy consumption than developing countries. The combination of these factors makes it difficult to reduce production costs to the levels of developing countries without adopting the support above and protection policies.

B) Impact on the volume of biofuel exports:

Policies in the United States of America are reflected in lower exports of biofuels to developing countries, as in the case of exports of 1 per annum ethanol to 1 United States of America, which fell by more than 59 per cent between 2006 and 2007 from 10.783 million Barrels to 4.403 million barrels, down 1 percent to more than 97 percent between 2008 and 2009 from 4.835 million barrels to 125,000 barrels; and 1 to exports from the Caribbean 1 and South America countries receiving preferential treatment, About the US Congress , As indicated by data on US imports of ethanol fuel from these countries; Congressional report shows that the low cost of imported ethanol from the Caribbean Basin countries represents a severe threat to locally produced ethanol, and therefore government support measures for this product represent a weapon to counter this threat.

The picture shows the volume of US ethanol imports from some Caribbean Basin countries, although they have benefited from preferential treatment and exemption from tariffs, and have not reached the ceiling of 7% of US market consumption, which can be explained by the impact of the policy Support domestic production.

Figure No 9: U.S. imports of Fuel Ethanol between 2007-2017



Source: U.S. Energy Information Administration. [Online]: " Petroleum & Other Liquids." 2017. WWW: <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MFEIMUS1&f=M>, Own graph

4.4. The impact of the use of food crops in the production of biofuels on prices:

4.4.1. Mechanisms of Biofuel Impact on Agricultural Commodity Prices:

The increasing use of biofuels is reflected in the relationship between supply and demand for primary agricultural commodities, due to the growing volume of these commodities in fuel production. This growing demand could affect agricultural commodity markets through three mechanisms, which could lead directly to higher prices of fuel used goods as a result of increased demand, as this could be

Indirectly influenced by high demand for alternative commodities, the high prices of corn or soybean oil, for example, as a foodstuff, lead consumers to replace them with other grains or edible oils. This substitution may also be in the production of biofuels itself, resulting in a positive correlation between prices Biofuel production and substitutes. On the other hand, the production of biofuels can affect the prices of agricultural commodities through the reallocation of agricultural land where the high prices of biofuel production materials push farmers to increase the cultivated area of these materials. This effect leads to higher prices due to lower production or transfer of production to less fertile land, which results in some kind of correlation between the prices of biofuel and other agricultural products that are grown in the same agricultural conditions, and can expand to other agricultural commodities because of the increase in the value of agricultural land to increase demand for the production of raw materials used in the production of biofuels.

4.4.2. The direct effect of biofuel production on corn prices:

To study the direct impact of biofuel production on crop prices, I measured the relationship between the price of corn and volumes used in the production of ethanol in the United States of America.

Table No.16: Time Series Data of Variables in the United States of America

Year	US $ per metric ton		Million bushels					
	Price of corn	**Price of wheat**	**The real total production of corn**	**Total official production of corn**	**Total exports of corn**	**Other use of corn production**	**Amounts of corn used in food**	**Amounts of corn used in Ethanol production**
1995	123.49	176.98	224.3595	213.7121	55.6956	117.3121	30.81233	9.892
1996	165.81	207.6	241.794	219.7133	44.93423	131.9263	32.1348	10.71803
1997	117.09	159.48	252.4701	219.775	37.61065	136.2619	33.7092	12.1933
1998	101.99	126.13	277.1324	232.4579	49.60483	136.3099	33.5977	12.9455
1999	90.22	112.04	280.8083	237.8696	48.41415	141.0691	34.24013	14.14618
2000	88.53	114.09	290.9856	243.5079	48.5337	145.5514	33.67717	15.74568
2001	89.64	126.81	285.2957	245.3851	47.6192	146.2187	33.86623	17.68096
2002	99.27	148.08	264.4415	237.2747	39.69718	138.7078	33.98209	24.8876
2003	105.37	146.14	279.701	255.7487	47.49543	144.531	34.53362	29.18869
2004	111.8	156.88	319.3626	266.5132	45.4514	153.3769	34.60464	33.08031
2005	98.67	152.35	330.8741	281.6951	53.3453	152.8765	35.39014	40.08311
2006	121.85	192.04	312.7567	280.1655	53.13423	138.5033	35.5406	52.98735
2007	163.66	255.21	359.0386	318.4348	60.93505	146.4435	34.82592	76.23035
2008	223.12	326.03	342.0221	301.4018	46.225	129.5464	32.90815	92.72223
2009	165.51	224.07	368.7203	326.0256	49.50953	127.5249	34.25	114.775
2010	185.91	223.58	354.0197	325.8285	45.77313	119.4174	35.16953	125.4685
2011	291.68	316.26	336.7744	312.0487	38.48343	112.975	35.6	125.0008
2012	298.42	313.24	297.6021	277.0725	18.25205	107.8754	34.91993	116.0282
2013	259.39	312.25	367.15	336.351	48.01233	126.0012	34.25	128.0923
2014	246.7	317.84	386.9773	343.6946	46.67208	131.9897	35.025	130.0023
2015	235.47	322.76	384.9956	341.5513	47.44078	128.244	35.725	130.1516
2016	225.53	324.18	423.5526	366.1785	57.3219	172.261	36.29833	135.9627
2017	216.74	325.88	423.675	364.875	51.25	138.75	36.75	138.125

Source: - USDA [online]: "Feed Grains: Yearbook Tables." 2017. WWW: <https://www.ers.usda.gov/webdocs/DataFiles/53657/All%20Tables%20in%20One.xls?v=43164>
- USDA [online]: "Feed Grains: Yearbook Tables." 2017. <https://www.ers.usda.gov/webdocs/DataFiles/53657/table05.xls?v=43164>
-World Bank, [Online]: “Commodity Markets.” 2018. WWW: <http://www.worldbank.org/en/research/commodity-markets>

A) Characterization of the model used:

To analyze the relationship between energy price changes, agricultural commodity prices and the impact of ethanol, a multi-regression model was adopted according to the method of the ordinary minimum squares as follows:

$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \varepsilon_t$

Where:

y: represents corn prices

x_1: represents the first explanatory variable and represents the quantities of maize used in the production of ethanol in the United States of America.

x_2: represents the second explanatory variable and denotes corn exports from the United States of America.

ε_t: represents the standard error limit.

Thus, the multiple linear regression equations required is:

$$CP = C + \beta_1 PM + \beta_2 EM + \varepsilon_t$$

Where:

CP: Corn prices are in dollars.

C: Unit vector.

PM: Quantities of corn used in the production of ethanol in the United States of America in tons.

EM: US corn exports by the ton.

ε_t: Represents the residual value.

Database:

I used the global corn price database of the World Bank for the price of maize and US Department of Agriculture data for maize quantities used in ethanol production and exports for 1995-2017.

B) Parameters estimation

To estimate regression parameters, I used the statistical program "EVIEWS 10," and the estimation outputs were as follows:

Dependent Variable: CP
Method: Least Squares
Date: 03/20/18 Time: 06:48
Sample: 1995 2017
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	200.4696	37.63396	5.326827	0.0000
PM	1.135065	0.121872	9.313613	0.0000
EM	-2.390650	0.754843	-3.167082	0.0048

R-squared	0.836333	Mean dependent var	166.3417
Adjusted R-squared	0.819966	S.D. dependent var	69.60670
S.E. of regression	29.53440	Akaike info criterion	9.730096
Sum squared resid	17445.61	Schwarz criterion	9.878204
Log likelihood	-108.8961	Hannan-Quinn criter.	9.767344
F-statistic	51.09963	Durbin-Watson stat	1.330772
Prob(F-statistic)	0.000000		

Source: Own calculation and elaboration.

From the outputs, the estimation equation is as follows:

$$CP = 200.47 + 1.135PM - 2.39EM + \varepsilon_t$$

From the previous table, I observe that the parameters of the estimation C, β_1, β_2 were significant according to the student's t-test for the regression constants at a significant level of 5% where (P value <0.05) for all constants.

The value of the Fischer coefficient 51.09 indicates that the constants are all significant at 5% (P-value =0, <0.05). The value of the corrected identification factor indicates that the estimated model interprets 81.99% of changes in the dependent variable by independent variables, which is a very high value.

C) Autocorrelation:

The value of Durbin Watson test (1.33) shows that there is no autocorrelation problem when compared to critical values at Freedom (2, 23).

D) Heteroscedasticity:

The results of the White test show that the model does not contain heteroscedasticity problem of variances by comparing Lagrange polynomial ($LM=nR^2=1.92$) with Chi-squared test value with two degrees of freedom ($\varkappa^2(2,0.05) = 5.99$) (Lagrange polynomial value is smaller than Chi-squared test value) as shown in the following table:

Heteroskedasticity Test: White

F-statistic	0.309149	Prob. F(5,17)	0.9007
Obs*R-squared	1.916994	Prob. Chi-Square(5)	0.8605
Scaled explained SS	1.133104	Prob. Chi-Square(5)	0.9511

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/20/18 Time: 07:29
Sample: 1995 2017
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5329.404	5963.853	-0.893618	0.3840
PM^2	0.070215	0.189965	0.369621	0.7162
PM*EM	-0.638187	0.798568	-0.799163	0.4352
PM	20.51798	43.75370	0.468943	0.6451
EM^2	-2.236129	2.053565	-1.088901	0.2914
EM	240.3268	213.4407	1.125965	0.2758

R-squared	0.083348	Mean dependent var	758.5048
Adjusted R-squared	-0.186256	S.D. dependent var	969.7242
S.E. of regression	1056.179	Akaike info criterion	16.98216
Sum squared resid	18963732	Schwarz criterion	17.27838
Log likelihood	-189.2948	Hannan-Quinn criter.	17.05666
F-statistic	0.309149	Durbin-Watson stat	1.186655
Prob(F-statistic)	0.900653		

Source: Own calculation and elaboration.

Also, the results of the ARCH test show that the model does not contain heteroscedasticity problem of variances by comparing Lagrange polynomial statistic (LM = nR2 = 3.51) with Chi-squared test value with two degrees of freedom $(\varkappa^2(2,0.05) = 5.99)$ (Lagrange polynomial value is smaller than Chi-squared test value) as shown in the following table:

Heteroskedasticity Test: ARCH

F-statistic	3.790235	Prob. F(1,20)	0.0657
Obs*R-squared	3.505017	Prob. Chi-Square(1)	0.0612

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/20/18 Time: 07:39
Sample (adjusted): 1996 2017
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	401.8449	244.9283	1.640663	0.1165
RESID^2(-1)	0.384612	0.197556	1.946853	0.0657

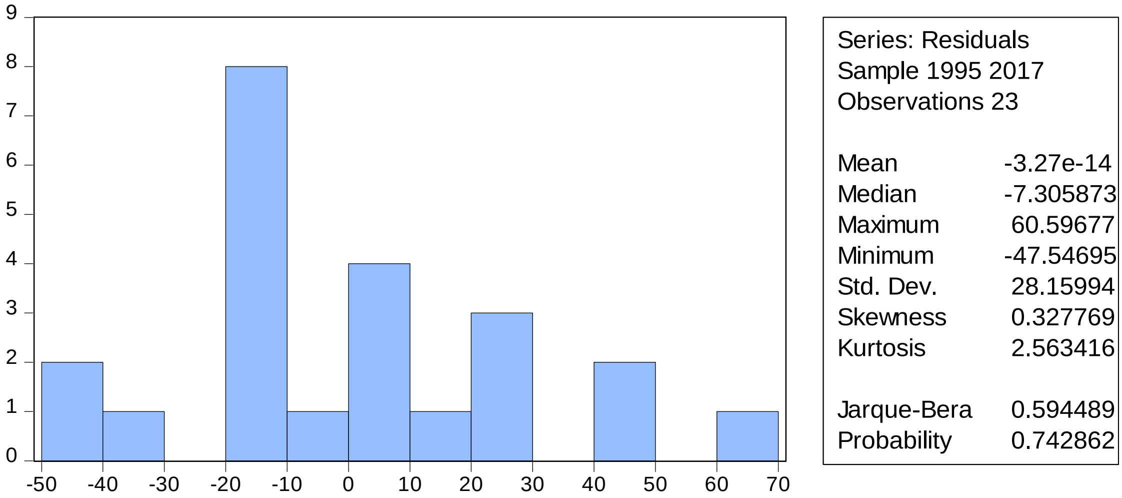
R-squared	0.159319	Mean dependent var	701.1778
Adjusted R-squared	0.117285	S.D. dependent var	951.8183
S.E. of regression	894.2611	Akaike info criterion	16.51638
Sum squared resid	15994059	Schwarz criterion	16.61557
Log likelihood	-179.6802	Hannan-Quinn criter.	16.53975
F-statistic	3.790235	Durbin-Watson stat	1.877808
Prob(F-statistic)	0.065734		

Source: Own calculation and elaboration.

E) Normality distribution test for residuals:

The Jarque-Bera test shows that the residues are distributed naturally by comparing the Jarque-Bera statistic value (**S** = 0.59) with Chi-squared test value with two degrees of freedom $(\varkappa^2(2{,}0.05) = 5.99)$ (as shown in the following table).

(The distribution is normal when the count of Jarque-Bera test is smaller than the value of Chi-squared test):



Source: Own calculation and elaboration.

F) Graphical chart of Residual analysis:

Source: Own calculation and elaboration.

G) Graphical chart of autocorrelation for residuals:

Date: 03/20/18 Time: 07:52
Sample: 1995 2017
Included observations: 23

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.380	0.380	3.7688	0.052
		2	-0.010	-0.180	3.7716	0.152
		3	-0.172	-0.119	4.6200	0.202
		4	-0.229	-0.137	6.2071	0.184
		5	-0.261	-0.175	8.3797	0.137
		6	-0.090	0.034	8.6542	0.194
		7	-0.088	-0.176	8.9300	0.258
		8	-0.069	-0.081	9.1103	0.333
		9	-0.044	-0.095	9.1899	0.420
		10	-0.170	-0.297	10.474	0.400
		11	-0.124	-0.080	11.210	0.426
		12	-0.098	-0.268	11.715	0.469
		13	0.165	0.133	13.287	0.426
		14	0.321	0.063	19.857	0.135
		15	0.294	-0.017	26.078	0.037
		16	0.039	-0.114	26.203	0.051

Source: Own calculation and elaboration.

H) Chow Breakpoint test:

I used the year 2005 as a base year because this is the year that the United States of America surpasses Brazil as the world's largest ethanol producer

Chow Breakpoint Test: 2005
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1995 2017

F-statistic	1.717449	Prob. F(3,17)	0.2013
Log likelihood ratio	6.088793	Prob. Chi-Square(3)	0.1074
Wald Statistic	5.152347	Prob. Chi-Square(3)	0.1610

Source: Own calculation and elaboration.

I) Explanation of the Equation:

From the linear regression equation, a positive correlation can be observed between the price of the corn and the quantities used in the production of ethanol through the positive sign of the regression constant, $\beta_1 = 1.135$. Also, an inverse relationship can be noted between the price of corn and the volume of corn exports through the negative sign of the regression constant, $\beta_2 = -2.39$. From the model, the proportion of the volume used from corn to total production increased from 4.628% in 1995 to 37.85% in 2017, which affected the volume of exports which fell from 26.06% to 14.05% of the same period. Also, the increase in the volume used from ethanol by one million ton lead to a rise in the price of corn by 1.135 dollars per ton, and the increase in the volume of exports by one million ton leads to a decline in the price of corn by 2.39 dollars per ton. Therefore, there is a proportionate importance to the rise in ethanol production coincided with declining exports on prices. It is true from an economic point of view, that the increasing in the use of corn in ethanol production will lead to higher corn prices and lower exports from corn. To calculate the corn price index based on the 1995, which is the base year, I calculated the Paasche price indices:

$$\text{Pp} = \frac{\sum(\rho t.qt)}{\sum(\rho 0.qt)}$$

Where the positive sign of change indicates higher prices. For example, in 2008 prices increased by 80.68% for the base year 1995 and increased by 36.33% for the previous year, as shown in the following table:

Table No 17: Evolution of corn price indices

Year	**Paasche price number for 1995**	**Change**	**Paasche variable price number**	**Changes**
1995				
1996	134.27%	34.27%	134.27%	34.27%
1997	94.82%	-5.18%	70.62%	-29.38%
1998	82.59%	-17.41%	87.10%	-12.90%
1999	73.06%	-26.94%	88.46%	-11.54%
2000	71.69%	-28.31%	98.13%	-1.87%
2001	72.59%	-27.41%	101.25%	1.25%
2002	80.39%	-19.61%	110.74%	10.74%
2003	85.33%	-14.67%	106.14%	6.14%
2004	90.53%	-9.47%	106.10%	6.10%
2005	79.90%	-20.10%	88.26%	-11.74%
2006	98.67%	-1.33%	123.49%	23.49%
2007	132.53%	32.53%	134.31%	34.31%
2008	180.68%	80.68%	136.33%	36.33%
2009	134.03%	34.03%	74.18%	-25.82%
2010	150.55%	50.55%	112.33%	12.33%
2011	236.20%	136.20%	156.89%	56.89%
2012	241.66%	141.66%	102.31%	2.31%
2013	210.05%	110.05%	86.92%	-13.08%
2014	199.77%	99.77%	95.11%	-4.89%
2015	190.68%	90.68%	95.45%	-4.55%
2016	182.63%	82.63%	95.78%	-4.22%
2017	175.51%	75.51%	96.10%	-3.90%

Source: Own calculation and elaboration.

4.4.3. The impact of the change in corn Prices on Wheat Prices:

A) Characterization of the model used:

The following model was used to study the relationship:

$$LWP = \alpha + \beta_1 LCP + \beta_2 LF$$

Where:

LWP: Logarithm of the wheat price.

α: Unit vector.

LCP: Logarithm Corn Price.

LF: Inflation logarithm.

Database:

I used the global corn price database of the World Bank for corn and wheat prices for the period 1995-2017:

B) Parameters estimation

To estimate regression parameters, I used EVIEWS 10, and the estimation outputs were as follows:

Dependent Variable: LOG(LWP)
Method: Least Squares
Date: 03/20/18 Time: 09:00
Sample: 1995 2017
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.713449	1.366251	-1.986054	0.0609
LOG(LCP)	0.541905	0.141475	3.830387	0.0010
LOG(LF)	1.171752	0.444970	2.633329	0.0159

R-squared	0.949889	Mean dependent var	5.328066
Adjusted R-squared	0.944878	S.D. dependent var	0.386725
S.E. of regression	0.090796	Akaike info criterion	-1.839300
Sum squared resid	0.164877	Schwarz criterion	-1.691192
Log likelihood	24.15195	Hannan-Quinn criter.	-1.802051
F-statistic	189.5568	Durbin-Watson stat	0.678598
Prob(F-statistic)	0.000000		

Source: Own calculation and elaboration.

From the outputs, the estimation equation is as follows:

$$LWP = -2.71 + 0.54LCP + 1.17LF$$

From the previous table, I observe that the parameters of the estimation β1, β2 are significant according to the student's t-test for the regression constants at a significant level of 5% where (P-value <0.05) for all constants while the constant α is not significant (P value> 0.05)

The value of the Fischer coefficient 189.56 indicates that all constants are significant at 5% (P-value = 0, <0.05). The value of the corrected coefficient indicates that the estimated model interprets 94.99% of changes in the dependent variable by independent variables, which is a very high value.

C) Autocorrelation:

The Durbin Watson statistic (0.68) shows that there is no self-correlation problem when compared to critical values at Freedom 2, 23.

D) Heteroscedasticity:

In contrast, the results of the White test show that the model does not contain the problem of heterogeneity of variances by comparing Lagrange multiplication statistic (LM = nR2 = 2.87) with a square kay value with two degrees of freedom (κ ^ 2 (2,0.05) = 5.99) Lagrange is smaller than the value of the square Kai) as shown in the following table:

Heteroskedasticity Test: White

F-statistic	0.484759	Prob. F(5,17)	0.7829
Obs*R-squared	2.870049	Prob. Chi-Square(5)	0.7200
Scaled explained SS	1.457227	Prob. Chi-Square(5)	0.9180

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/20/18 Time: 09:04
Sample: 1995 2017
Included observations: 23

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.159088	7.923679	-0.272485	0.7885
LOG(LCP)^2	-0.021799	0.098771	-0.220706	0.8280
LOG(LCP)*LOG(LF)	0.190483	0.610850	0.311832	0.7590
LOG(LCP)	-0.633001	1.812357	-0.349269	0.7312
LOG(LF)^2	-0.297611	0.923494	-0.322266	0.7512
LOG(LF)	1.692741	5.400139	0.313463	0.7577

R-squared	0.124785	Mean dependent var	0.007169
Adjusted R-squared	-0.132632	S.D. dependent var	0.008494
S.E. of regression	0.009040	Akaike info criterion	-6.354886
Sum squared resid	0.001389	Schwarz criterion	-6.058670
Log likelihood	79.08119	Hannan-Quinn criter.	-6.280388
F-statistic	0.484759	Durbin-Watson stat	1.619503
Prob(F-statistic)	0.782920		

Source: Own calculation and elaboration.

The results of the ARCH test show that the model does not contain a problem of homogeneity of discrepancies by comparing Lagrange multiplier count (LM = nR2 = 1.4) with a square ky value with two freedom ratings (κ ^ 2 (2,0.05) = 5.99) Value square kai) as shown in the following table:

Heteroskedasticity Test: ARCH

F-statistic	1.359908	Prob. F(1,20)	0.2573
Obs*R-squared	1.400660	Prob. Chi-Square(1)	0.2366

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/20/18 Time: 09:06
Sample (adjusted): 1996 2017
Included observations: 22 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.005617	0.002414	2.327170	0.0306
RESID^2(-1)	0.250989	0.215229	1.166151	0.2573

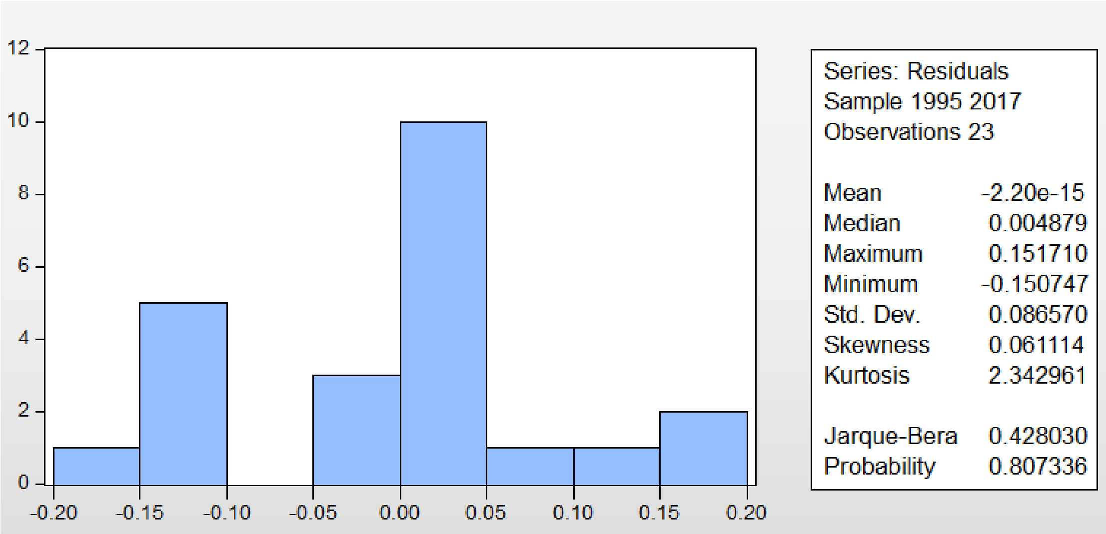
R-squared	0.063666	Mean dependent var	0.007480
Adjusted R-squared	0.016850	S.D. dependent var	0.008559
S.E. of regression	0.008486	Akaike info criterion	-6.614258
Sum squared resid	0.001440	Schwarz criterion	-6.515072
Log likelihood	74.75684	Hannan-Quinn criter.	-6.590893
F-statistic	1.359908	Durbin-Watson stat	1.900440
Prob(F-statistic)	0.257272		

Source: Own calculation and elaboration.

E) Normality distribution test for residuals:

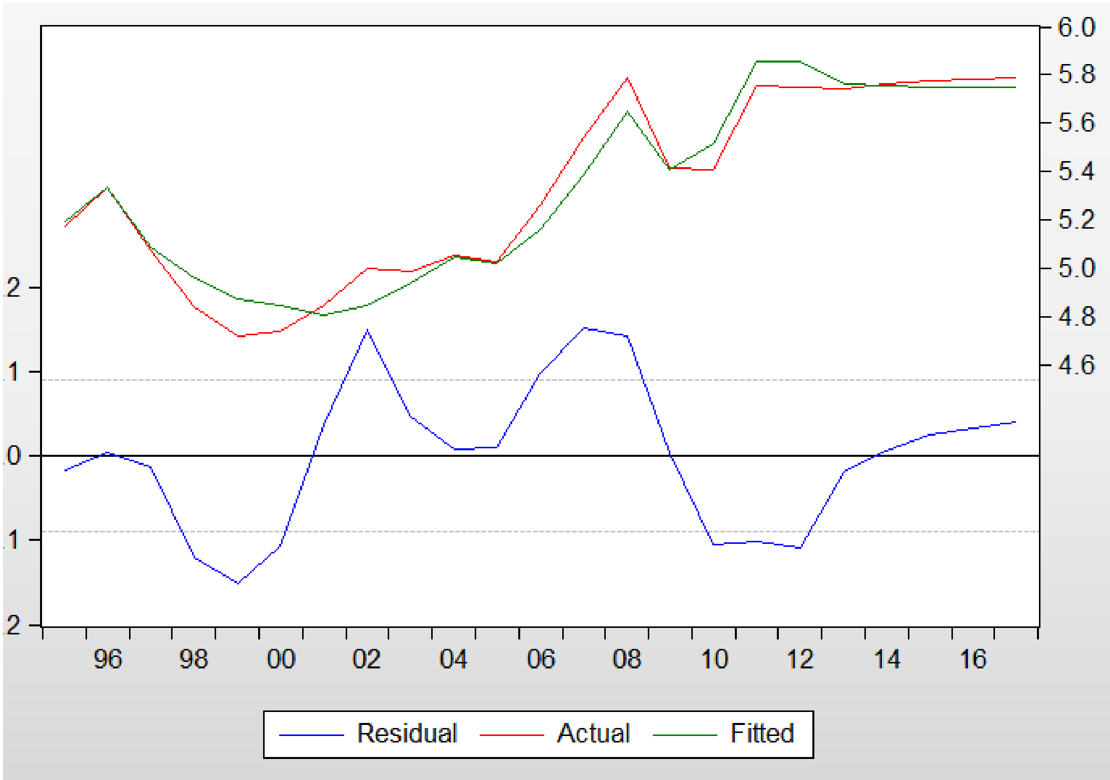
The Jarque-Bera test shows that the residues are distributed naturally by comparing the Jarque-Bera statistic value (**S** = 0.43) with Chi-squared test value with two degrees of freedom $(\varkappa^2(2,0.05) = 5.99)$ (as shown in the following table).

(The distribution is normal when the count of Jarque-Bera test is smaller than the value of Chi-squared test):



Source: Own calculation and elaboration.

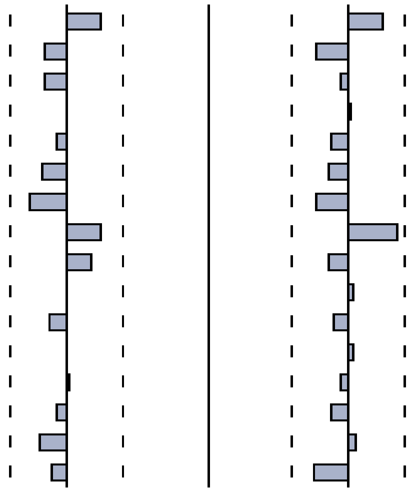
F) Graphical chart of Residual analysis:



Source: Own calculation and elaboration.

G) Graphical chart of autocorrelation for residuals:

Date: 03/20/18 Time: 09:09
Sample: 1995 2017
Included observations: 23



	AC	PAC	Q-Stat	Prob
1	0.247	0.247	1.5935	0.207
2	-0.159	-0.234	2.2848	0.319
3	-0.158	-0.059	3.0059	0.391
4	-0.005	0.024	3.0066	0.557
5	-0.069	-0.133	3.1586	0.676
6	-0.177	-0.149	4.2167	0.647
7	-0.264	-0.239	6.7236	0.458
8	0.248	0.359	9.0838	0.335
9	0.184	-0.143	10.474	0.314
10	0.006	0.028	10.475	0.400
11	-0.137	-0.102	11.371	0.413
12	-0.002	0.028	11.371	0.497
13	0.013	-0.064	11.381	0.579
14	-0.080	-0.137	11.787	0.623
15	-0.204	0.043	14.776	0.468
16	-0.100	-0.250	15.600	0.481

Source: Own calculation and elaboration.

H) Chow Breakpoint test:

I used the year 2005 as a base year because this is the year that the United States of America surpasses Brazil as the world's largest ethanol producer

Chow Breakpoint Test: 2005
Null Hypothesis: No breaks at specified breakpoints
Varying regressors: All equation variables
Equation Sample: 1995 2017

F-statistic	2.908744	Prob. F(3,17)	0.0647
Log likelihood ratio	9.528849	Prob. Chi-Square(3)	0.0230
Wald Statistic	8.726231	Prob. Chi-Square(3)	0.0332

Source: Own calculation and elaboration.

I) Explanation of the Equation:

From the linear regression model, a positive correlation can be observed between the price of wheat and the price of corn through the positive sign of the regression constant β_1 =0.54. If the price of corn increases one dollar per ton, then the price of wheat will increase 0.54 dollar per ton, and this result is consistent with the economic substitution effect, where the prices of cereals are rising simultaneously whether they are used in the production of ethanol or not. The following table shows the change in wheat and corn prices depending on the base year 1995 and on the previous year.

Table No 18: Evolution of wheat and corn price indices

Year	Wheat price change 1995	Corn price change 1995	Index number for price change 1995	Amount of change	Wheat price change	Corn price change	Index number for price change	Amount of change
1996	117.30%	134.27%	125.79%	25.79%	117.30%	134.27%	125.79%	25.79%
1997	90.11%	94.82%	92.46%	-7.54%	76.82%	70.62%	73.72%	-26.28%
1998	71.27%	82.59%	76.93%	-23.07%	79.09%	87.10%	83.10%	-16.90%
1999	63.31%	73.06%	68.18%	-31.82%	88.83%	88.46%	88.64%	-11.36%
2000	64.46%	71.69%	68.08%	-31.92%	101.83%	98.13%	99.98%	-0.02%
2001	71.65%	72.59%	72.12%	-27.88%	111.15%	101.25%	106.20%	6.20%
2002	83.67%	80.39%	82.03%	-17.97%	116.77%	110.74%	113.76%	13.76%
2003	82.57%	85.33%	83.95%	-16.05%	98.69%	106.14%	102.42%	2.42%
2004	88.64%	90.53%	89.59%	-10.41%	107.35%	106.10%	106.73%	6.73%
2005	86.08%	79.90%	82.99%	-17.01%	97.11%	88.26%	92.68%	-7.32%
2006	108.51%	98.67%	103.59%	3.59%	126.05%	123.49%	124.77%	24.77%
2007	144.20%	132.53%	138.37%	38.37%	132.89%	134.31%	133.60%	33.60%
2008	184.22%	180.68%	182.45%	82.45%	127.75%	136.33%	132.04%	32.04%
2009	126.61%	134.03%	130.32%	30.32%	68.73%	74.18%	71.45%	-28.55%
2010	126.33%	150.55%	138.44%	38.44%	99.78%	112.33%	106.05%	6.05%
2011	178.70%	236.20%	207.45%	107.45%	141.45%	156.89%	149.17%	49.17%
2012	176.99%	241.66%	209.32%	109.32%	99.05%	102.31%	100.68%	0.68%
2013	176.43%	210.05%	193.24%	93.24%	99.68%	86.92%	93.30%	-6.70%
2014	179.59%	199.77%	189.68%	89.68%	101.79%	95.11%	98.45%	-1.55%
2015	182.37%	190.68%	186.53%	86.53%	101.55%	95.45%	98.50%	-1.50%
2016	183.17%	182.63%	182.90%	82.90%	100.44%	95.78%	98.11%	-1.89%
2017	184.13%	175.51%	179.82%	79.82%	100.52%	96.10%	98.31%	-1.69%

Source: Own calculation and elaboration.

5. Conclusion

Given the current problems of the current energy pattern and the diversity of alternative energy sources, it is arguable that what the world is currently experiencing is not a problem of energy. Rather, the world is facing a technological challenge to develop renewable energy sources and to make them more suitable to replace traditional sources of energy in various fields of use, primarily the fuel for transportation. This leads us to deny the first hypothesis that the world is experiencing a multidimensional energy crisis as a result of the depletion of traditional energy sources and their environmental effects. By discussing the importance of biofuels as an alternative to fuel oil, the status of biomass energy has been highlighted as one of the most important renewable energy sources, which is increasingly used in total energy consumption in the world. The biomass energy has the potential for being utilized in various fields of modern energy use. The vast potential for producing biomass energy and its availability in different regions of the world makes it one of the most critical alternatives to fossil fuel. Therefore, biomass energy sources can be relied upon to provide part of the energy requirements for the transport sector in the context of the direction to replace suitable fuel oil alternatives. Biofuels can be considered a modern form of bioenergy and the real and practical alternative to oil derivatives in the transport sector. Thus, the biofuel attracts a growing interest in many countries racing for the development of the production and the use of it and work to replace the destructive oil fuel.

Through the analysis of biofuel production policies in the United States of America, it was found that the massive expansion of biofuel production would not have been possible without the government support. These governmental policies include a set of support tools, mainly; tax incentives, quantitative targets, subsidies and customs tariffs that aims to protect local production. These policies are motivated by economic and environmental demands. They aim to meet the challenge of reducing the energy dependence, especially towards oil.The ability of biofuels to compete with fossil fuel in the current conditions depends heavily on the production and consumption support policies.

Biofuels face some weaknesses in the competition with fossil fuels under the influence of many factors. One of the limiting factor of the use of the biofuels is the fluctuation of oil prices and agricultural raw materials prices used in biofuel production.

Additionally, the use of biofuels represents a real challenge to food security. It represents a competitor to food commodities destined for human consumption, because of the high demand created on these resources to meet the target production for volume under the implemented governmental programs. Furthermore, the growing demand for biofuels puts pressure on water resources and agricultural land.

Biofuels are also a challenge to food security due to their direct impact on the availability of cereals and vegetable oils, which are the primary source of fuel production. This effect is evident in the increase of the prices of these crops and the decrease of their exports in the United States of America. This, ultimately, had an impact on the prices of these commodities in the international markets. From the linear regression equation, a positive correlation can be observed between the price of the corn and the quantities used in the production of ethanol. The increased use of corn as a significant source of biofuels in the United States has led to a sevenfold increase in ethanol production since 1995. As a result, the US maize exports have declined by about a third, and ethanol production has increased corn prices. These results are consistent with the economic principles. Also, from the model, there is a positive correlation between the price of wheat and the price of corn in the United States of America. If the price of corn rises by a certain amount, the price of wheat will rise by half of that rise, which is a natural consequence of substitution. Thus, the expansion of the use of corn in the production of biofuels will naturally lead to higher prices of the corn substitutes due to the increased demand.

Biofuel, like other sources of energy, has advantages and disadvantages. On the one hand, it represents an alternative to the depleted oil energy. On the other hand, biofuel impacts the crops used in its production. This impact extends to the markets of the most basic agricultural commodities through the effect of substitution between crops and by competing with other crops on agricultural land and water resources.

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