Czech University of Life Sciences Prague

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Diploma Thesis

Price correlation between sugar and biofuels in Brazil

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Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

Denisa Sedláková

European Agrarian Diplomacy

Thesis title

Price correlation between sugar and biofuels in Brazil

Objectives of thesis

The largest producer and supplier of sugar cane in the world is Brazil and according to scientific research publications, Brazil also produces 50% of bioethanol made from sugar cane. The main objective of this thesis is to identify whether the price correlation of sugar and biofuels affect the food price increase in Brazil. Furthermore to find out if Brazil is behind the increasing sugar prices in the world. Also whether the price movement affects the market price of mentioned commodities.

Methodology

Diploma thesis is composed into two parts. The first one is theoretical part describing and defining the basic notions and terminology regarding to sugar and biofuel history, development, its worldwide production and consumption and all relates to the situation in Brazil according to the literature. The practical part is afterwards devoted to analysis data using methods of analysis, synthesis and comparison. Obtained statistical data retrieved from FAOSTAT, OECD, MŽP, statista organisation are used to determine price development of both commodities in 10 years period in that particular country. Using development charts and graphical data assessment method to compare these facts and on this basis evaluate whether there is a correlation with results interpretation.

The proposed extent of the thesis

60 – 80 pages

Keywords

Sugar, Biofuels, Brazil, Correlation, Price development, Analysis

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Recommended information sources

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Expected date of thesis defence

2017/18 SS – FEM

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Prague on 22. 03. 2018

Declaration

I declare that I have worked on my diploma thesis titled "Price correlation between sugar and biofuels in Brazil" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any other person.

In Prague on date ______________________________

Acknowledgement

I would like to thank doc. Ing. Mansoor Maitah, Ph.D. et Ph.D. for his helpful guidance in writing this thesis, for his patience and helpful advice. I also want to thank to my employer EYELEVEL for his expert advices.

Price correlation between sugar and biofuels in Brazil

Abstract

The main aim of this thesis is to examine, whether there is dependence between the price of sugarcane and biofuels in Brazil and how these two variables affect each other. Brazil is a diverse country which holds a high position among exporters, producers and consumers of ethanol. Brazilian ethanol is processed from sugarcane, which is also a very cultivated crop in the country. Brazil annually produces up to 50% of bioethanol produced from sugarcane. The theoretical part describes theories of sugarcane and ethanol influences in Brazil and in the international market as well as the export, import, production, consumption, price development from a given time period and history of both commodities.

For the calculation in practical part, it is used two equation econometric model, and based on the output from the mathematical-statistical Ordinary least squares method (OLS), was found out, that sugarcane price is not so much influenced by the ethanol price as the harvested area (0.84%), sugarcane production (2.84%) or crude oil price - global (0.35%). Ethanol price affects the sugarcane price by 0.14%. The second examined variable was ethanol production in Brazil, that is mostly affected by crude oil consumption in Brazil (0.56%), sugarcane price (0.27%) and crude oil price from a very small part (0.094%).

Keywords: sugar beet, sugarcane, biofuels, price

Cenová korelace mezi cukrem a biopalivy v Brazílii

Souhrn

Hlavním cílem této práce je zjistit korelaci mezi cenou cukru, biopaliv v Brazílii a ostatními vybranými vlivy. Brazílie je rozmanitá země, která si drží vysokou pozici mezi exportéry, producenty a konzumenty etanolu. Brazilský ethanol se vyrábí z cukrové třtiny, která je v zemi velmi oblíbenou plodinou k pěstování. Ročně se v Brazílii vyprodukuje až 50% bioethanolu, který je zpracován z cukrové třtiny. V teoretické části jsou popsány teorie vlivů cukrové třtiny a ethanolu v Brazílii i na mezinárodním trhu; export, import, produkce, spotřeba, cenový vývoj v daném čase a historie obou komodit.

Praktická část zjišťuje, zda-li je mezi cenou cukru a biopalivy v Brazílii závislost a jak se tyto dvě proměnné ovlivňují navzájem. K těmto výpočtům je použit dvourovnicový ekonometrický model a na základě výstupů z matematicko-statistické Metody nejmenších čtverců, bylo zjištěno, že cena cukru není ani tak ovlivněna cenou etanolu, jako sklizňovou plochou cukrové třtiny (0,84%), produkcí cukrové třtiny (2,84%) nebo celosvětovou cenou ropy (0,35%). Cena etanolu ovlivňuje cenu cukrové třtiny 0,14%. Druhou zkoumanou proměnnou byla produkce etanolu v Brazílii, ta je převážně ovlivněna spotřebou ropy v Brazílii (0,56%), cenou cukrové třtiny (0,27%) a z velmi malé části i cenou ropy (0,094%).

Klíčová slova: cukrová řepa, cukrová třtina, biopaliva, cena

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1 Introduction

Sugar and bioethanol belogs to the most important commodities on the world`s market forced by the strong pressure of globalization. Sugar is an indispensable part of our lives. According to experts, most of the population use sugar basically everyday as part of daily consumption of beverages such as coffee, tea, and receiving sugar all day not only by consuming sweet drinks but also with other meals. Surprisingly, the high content of sugar occurs in a big amount of food even with a salty flavor such as tomato sauce, ketchup, Pringles, Redbull, yoghurt. Sugar is also in many kinds of semi-finished products, sandwich and fast food. In almost all foodstuffs is at least a small amount of sugar or is flavored by sugar.

There are still a lot of questions about chemical inputs used for sugar production such as environmental footprint caused by production and even consumption, a health point of view by consuming sugar, or sugar association with biofuels production. All these questions have different hypothesis, opionions and answers provided by experts whether they are positive or negative it is necessary to take into account, that sugar production contributes to development especially in developing countries. The positive impact is introduced by providing employment and reliable incomes for many poor individuals but the negative issues can be harmful for whole population mostly associated with food production for instance poor working conditions, child labour and increasing food prices for instance in Brazil.

Sugar production limitations can be devastating for multinational companies such as Coca-Cola buying significant amount of sugar every year (around 145 million tonnes). So is it even possible to reduce the amount of greenhouse gases caused by sugar production, decreased chemical inputs, improve the working conditions of employees, increase income and yet keep the price of sugar stable and low?

Sugarcane cultivated in Brazil is third most important crop after soybean. Brazil produce 25% of world sugar and ethanol in the world. Also has relatively high domestic consumption of ethanol around 90% and according to data from the year 2011 also largest exporter of sugar.

Biofuels are considered as a substitute (gasoline additive and extender) for expensive fuels made from crude oil. Oil and natural gas rank among the non-renewable resources, so the world is looking for alternatives. For the last 30 years Brazil has managed to become a leader in renewable energy. Brazil as the largest sugarcane producer from which ethanol is produced, and that is part of biofuels. Ethanol can be also produced from carbohydrates such as starch and cellulose by fermentation using yeast or other organisms. Brazil is the second largest producer of ethanol after the US. According to ecologists, ethanol production in Brazil basically increases the food prices and destroys forests.

2 Objectives and methodology

2.1 Objectives

The aim of this thesis is to analyze studies about the price correlation between the sugar and biofuels. There is a relationship between these two commodities, which affects its prices and therefore demand and supply. Sugar, as we know in its current form, has been a commodity known for several hundred years, but references to crude form have been known since the ancient times. The history of biofuels has been relatively short, known for few decades. The production of ethanol from carbohydrate is needed for biofuels production. The price of biofuels is therefore known shortly.

The largest producer and supplier of sugarcane in the world is Brazil and according to scientific research publications, Brazil also produces 50% of bioethanol made from sugarcane. The main objective of this thesis is to identify, whether there is dependence between the price of sugarcane and biofuels in Brazil and how these two variables affect each other. Furthermore to find out, if Brazil is behind the increasing sugar prices in the world and also, whether the price movement affects the market price of mentioned commodities.

2.2 Methodology

Diploma thesis is composed into two parts. The first one is theoretical part describing and defining the basic theories and terminology regarding to sugar and biofuel history, development, its worldwide production and consumption related to the situation in Brazil according to the literature. The practical part is afterwards devoted to analysis data using methods of analysis, synthesis and comparison. Obtained statistical data retrieved from FAOSTAT[1], OECD[2], STATISTA, USDA[3], OEC[4], CEPEA[5], ABEGAS are used to determine price development of both commodities in 18 years period within particular country. Using development charts and graphical data assessment methods are used to

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[1] Food and Agricultural Organization of the United Nations

[2] Organisation for Economic Co-operation and Development

[3] U.S. Department of Agriculture

[4] The Observatory of Economic Complexity

[5] Center for Advanced Studies in Applied Economics

compare these facts and on this basis evaluate whether there is a correlation with results interpretation. Last but not least, as a methodology it is used econometric modelling for estimating the correlation among Sugarcane price, harvested area, export, production and ethanol price; Ethanol consumption in Brazil as well as the ethanol production, crude oil price and a number of cars powered by biofuels in Brazil. All these estimated parameters might have influence on sugarcane price and ethanol production either positively or negatively. For calculating elasticity, estimating statisticial significant parameters and dependency, it is used OLS with two equation model and coefficient of determination (R^2).

3 Theoretical part

3.1 General information about Federative Republic of Brazil (Brazil)

Brazil is the largest Portuguese speaking nation in the world and the largest country in the South America. Brazil is sharing borders with Peru, Paraguay, Venezuela, Colombia, Bolivia, Argentina, Uruguay, Guyana, Suriname and French Guiana. In 1822, Brazil become independent from Portugal and has become as a federal republic with 26 states and capital city Brasília as the only one federal district. The main industries in the country are power generation, tourism, lumber, chemicals and motor vehicles. Most of the land is used for forests (61.9%), agriculture (32.9%) and others (5.2%). Climate is mostly tropical. The country is also facing to recurring droughts in the northeast and floods, occasional frost in south. (Appendix 4) GDP[6] of Brazilian industry reached up towards 22.7% in 2016 of which services were 72%. Estimated GDP per capita was $15,200 (PPP) for 2016. Higher unemployment affected the country with increasing value since the year 2014 (4.5%), 2015 (6.4%) and 2016 (11.8%). The main sector of employment are industry, agriculture and services (Belanger C., 2017).

Total population in Brazil reaches up to 207 million people with stable middle class and predominantly urban inhabitants (86%). Since 2000, the country has expanded on a large scale with more than 21 million households compared to the previous year with 12.5 million households. By the 2021 the estimation of increasing household is 22.3 million. Brazil is recovering from a long recession and politically has been done changes in country´s leadership, however the unemployment rates are estimated to become at single-digit level again (as it was before the recession in 2009). The upper middle class income in Brazil is over $50,000[7] (2016), whereas a high gap between middle income and low income households (which did not change a lot for decades) come up to $20,000 (PPP). (USDA, 2017) Brazil is a member of BRIC association with Russia, India, and China, together forming the group of the fastest growing economies. Brazil also has 7th biggest economy in the world (Statista, 2017).

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[6] Gross Domestic Product

[7] Purchasing Power Parity 2005 (PPP) - exchange rate between 2 currencies is equal to the ratio of the currencies' respective purchasing power.

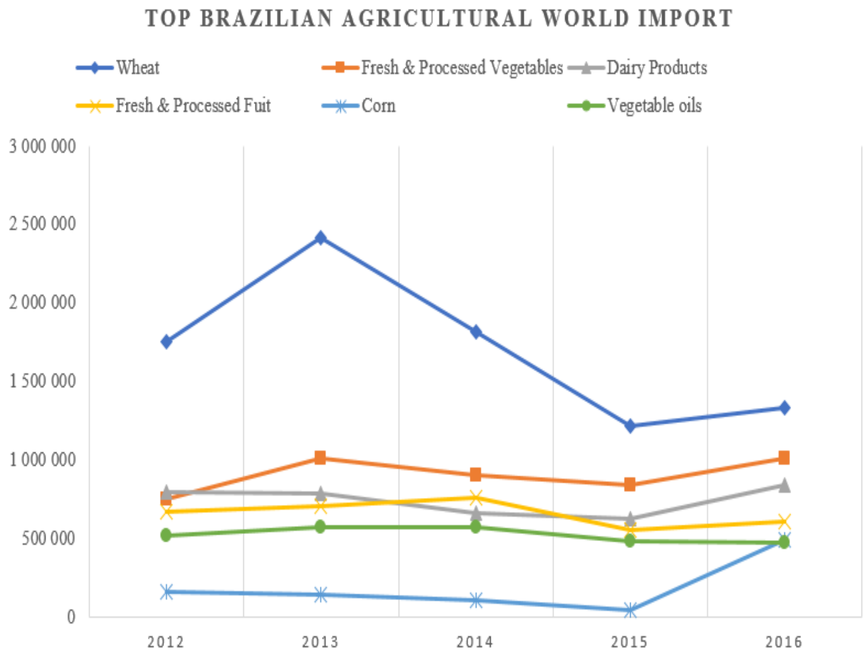
Import

Brazil's economy is recovering from a one of the historically worst eight - quarter - long recession and its middle class is growing. Nowadays consumers are demanding more quality with higher-value food products and modifying their consuming habits, making opportunities for US by rebranding well-known premium brands to create less-expensive products. Importing tools for promoting products sales are bonus packs and price discounts, so the consumers are interested in better purchasing deals. According to research papers this shows that Brazilian's consumers are more into purchasing not the quantity but the quality products. That is why the long term projection of retail food and beverage sales to the year 2021 is increasing (USDA, 2017).

Brazilian, the most world imported commodities since 2012 have been wheat and fresh/processed vegetables. After wheat, the highest import is followed by fresh and processed vegetable and fruit, dairy products, vegetable oils and corn (Graph 1). Brazil is a member of World Trade Organisation (WTO) since 1995 and due to which, the import in the country has doubled. By 2016, there were imported $10 billion of agricultural products. Brazil is also a member of The Common Market of the South[8], together with Argentina, Brazil, Paraguay, Uruguay and Venezuela (and other associate countries). Argentina, Paraguay, United States and European Union are the main importers to Brazil based on data by the year 2016. The aim of the agreement is to enhance a movement of goods, services and currency. In 2016, 50% of agricultural import in Brazil, were supplied by the mentioned Mercosur countries whereas the US imported only 8% to the country (USDA, 2017).

[8] "*Mercosur is a free trade agreement with both full members and associate countries that includes elimination of customs rights and lifting of non-tariff restrictions on the transit of good, services, and factors of production among its members.*" *(USDA, 2017)*

Graph 1 Top Brazilian Agricultural World Import in period 2012 – 2016.

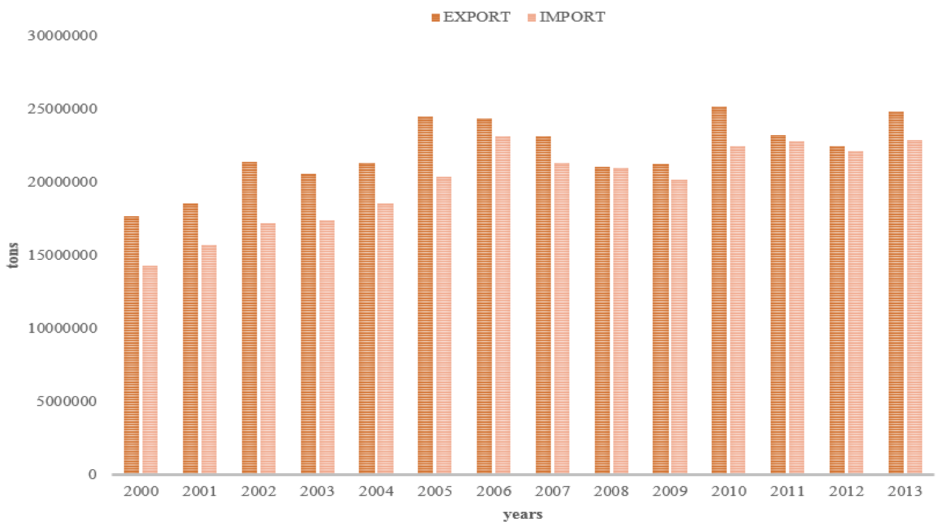


Source: Author's elaboration based on retrieved data from USDA, 2017.

By the year 2012 the total world sugar ammount that was that year traded on international market was around 56 million tonnes. According to data, the projection of traded sugar globally is going to be 65 million tonnes in 2022. Brazil is dominant in the raw sugar market with high sugarcane production (Commodity basis, 2014). While for the next ten years, the expected average of sugar production should reach to 210 million tonnes by the year 2025 (OECD/FAO, 2016). World demand 20 - 25% is estimation for international sugar trade. Comparing to other commodities world demand (10 – 20%), the sugar demand is high (Commodity basis, 2014).

By retrieved data from FAOSTAT, the total world sugar import was always lower than export in period 2000 – 2013 (Graph 2). In 2008, import and export of sugar were balanced, almost as well as in 2011 where the value of import of sugar (22.8 million tonnes) was shightly behind sugar export (23.1 million tonnes) and still in 2012, lower import with 22.1 million than export with 22.4 million tonnes. The highest sugar import was in 2006 with 23.1 million tonnes while the highest export was in 2010 with 25.1 million tonnes.

Graph 2 Total World Export and Import of refined sugar in 2000 – 2013.



Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

Export

In 2014, the total Brazilian export reached 225 billion US dollars. Two years later (2016) the total export was lower by less than 40 billion US dollars (US$ 185), according to OEC it was US$ 182. China has become very important for Brazilian exports, participated by 17% (2012) on Brazilian export. According to the publications, if the export gets incredibly high the import would be much higher (Statista, 2017).

In the 2016, Brazil exported 48% of raw sugar (10.4 billion US dollars) worldwide. India imported the highest amount (8.5%) of Brazilian raw sugar in 2016 following by China (7.9%) and Bangladesh (6.4%).

3.2 Sugar

3.2.1 History of sugar situation in the EU and abroad

In the past, sugar has been considered as a symbol of luxury. How time passed by, it has become a daily used commodity for the whole population. Sugar, as we know today, is made from sugarcane or sugar beet, where the history of sugarcane *(Saccharum officinarum)* cultivation (as a crude forms of sugar) was domesticated in Papua New Guinea about 6000 BC. The cultivation was gradually expanded to the area of Mesopotamia, Morocco, southeastern Spain and India. From 14th century, the cultivation was brought on islands such as Madeira, Canary Islands as well as to Haiti and Cuba. History of sugar beet *(Beta vulgaris var. Altissima)* is a lot shorter than sugarcane history (Andel, etc., 2013). From the reason that sugarcane was and still is cultivated in tropical and subtropical areas, sugar beet was firstly identified as an alternative source of sugar which was possible to cultivate in temperate regions. The mid-18th century did not sufficiently developed processing methods, where the sugar from the sugar beet could not been produced in Europe until 19th century even when attempts have been successful for quite some time (Cheesman, O., 2004). Sugar imported to Britain came from the Arab world where the Venetians (sugar controllers) bought it from the Middle East and shipped it out to every other European nation. In 13th century, sugar was very expensive, purchased only by Royal palaces and still very rare for consumers. It was documented by marveously detailed images of desserts statues made of sugar. Some of them were 1,8 meters high arts created on the festive dinner tables. Ordinary people ate food to sustain themselves, wealthy people used sugar to just show off.

Before sugar became known as a food sweetener, honey used to be considered as the oldest world's sweetener. It was known already in the ancient Egypt 3500 BC refered in written papyrus called *The Book of preparation of medicines for all parts of the human body*. Papyrus includes several recipes in which the honey is considered as a medicine which has healing effects. Honey was also part of the Egyptian burial cults as well as a beauty product which, according to the information, was popularized by the Egyptian Queen Cleopatra. Also in many ancient cultures, honey was a sign of fertility (ČSV, 2017). In 17th century, sweetener used in America, was maple syrup boiled from maple trees while carob[9] was used in Mediterranean area (Edwards C., 2016).

Over the past 20 years, sugar beet has changed from a large crop of lowland areas in a special crop, which is dedicated to a limited circle of about 800 planters where sugar refineries remained. However, at the same time, yields have doubled, growing cultivation technology improved and became more complicated. New way of using sugar was implemented for bioethanol production (Chochola J., 2010). Nowadays the concentration of sugarcane production is currently extremely high, mainly in Brazil and India. Together it is harvested over a half of the world's total (Brazil itself harvests 40%). In 1961, Brazil together with Cuba, was second in production, while in Cuba the harvest fell down, in Brazil it has

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[9] Carob is a powder made from the ground pods and seeds of Mediterranean tree *(Ceratonia siliqua)* and used in cooking, especially as a substitute for chocolate. (Dictionary.com 2017)

increased by 12 times. The main reason was the fact that 60% of sugarcane was directed to bioethanol production and the rest for sugar production (Pokorna I., etc., 2011).

3.2.2 Sugar world and EU production and consumption

Sugar production

Sugarcane is produced in around 120 countries, mostly where tropical areas are located. However, sugar beet can be found in temperate regions such as parts of Spain, North Africa, Iran and Pakistan, where both, sugar beet and sugarcane, can be grown. Since 1960, India and Brazil were in the spotlight of high production, ranging between 3-15 million tonnes per annum (Cheesman, O., 2004). From the year 1960 to the 90's of the 20th century, production decreased in countries such as Cuba and Barbados (Hartemink A., 2005). Brazilian sugarcane economy generates US $36 billion in gross anual revenues and includes 1million of employees in sugarcane sector (UNICA, 2015).

World sugar production is increasing every year. Total production is influenced by many factors such as macroeconomic conditions and national policies (OECD/FAO, 2016). Climate change in the case of drought can reduce harvest and since the population is still growing and sugar demand is growing as well, production has been increased 2.9 times over the last 25 years (Sukova I., 2011). Any changes in these factors may be reflected in sugar demand, sugar supply and its prices (OECD/FAO, 2016).

According to research there is a certain trend indicating a gradual share decrease of sugar beet in favor of sugar produced from sugarcane. During the years (1961 - 2011) when it was monitored, production of sugarcane increased almost by 4 times, however sugar beet increased only by 70%. World sugar production tripled from 53 million tonnes to 156 million tonnes (Pokorna I., etc., 2011).

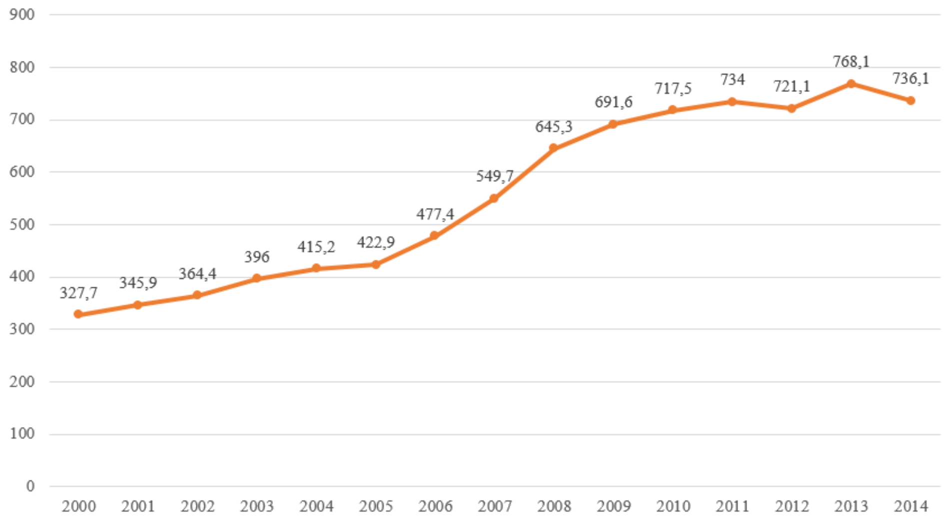
´´World sugar production is projected to grow by 1.7% p.a. to reach 210 Mt by 2026.´´ (OECD/FAO, 2016)

Annually 168 million tonnes of sugar is produced worldwide, which is around 25kg per person (Foodnet, 2017). According to Statista 2017, 165.8 million tonnes of sugar were produced worldwide in years 2015 - 2016. In 2017 the sugar production should reach to

170.81 million tonnes compared with 2006 when total world production was lower and reached to 114 million tonnes per annum (Pokorna I., etc., 2011).

Since the year 2000, Brazil has been the largest sugarcane producer and exporter. It is assumed that Brazilian sugarcane production will continue influencing the sugar market. For the next ten years, the expected average of sugar production increase is by 2.1% per annum and should reach to 210 million tonnes by the year 2025. Sugar demand should increase by 2% per annum and by the year 2025 stock-to-use ratio should decrease from 45% to 39%. Sugar is cheap and affordable source of energy which can be easily stored and transported. According to FAO data, there will not be changes in consumer habits in developing countries with high calorie intake (OECD/FAO, 2016). Sugarcane cultivated in South America, Africa and Asia is going to remain a main crop (OECD/FAO, 2017).

Graph 3 Total Sugarcane production in Brazil 2000 – 2014 (million tonnes).



Source: Author's elaboration based on data retrieved from FAOSTAT, 2017.

It can be expected that Brazil will retain the role of the largest sugar producer and supplier to the future (OECD/FAO, 2016). There are 10 countries (Figure 1) displayed with the largest sugarcane production by the year 2014 (FAOSTAT, 2017). The UNICA[10] group announced that in 2016/2017, sugar production in Brazil was a record, that reached up to

[10] UNICA is Brazilian sugarcane industry association.

35.6 million tonnes, increased by 14.1% over the previous year (Foodnet, 2017). Sugar produced in Brazil reaches to 25% global and around 50% of world exports. Brazil exports 24.2 million tonnes (80% of raw sugar, 20% of refined sugar[11]) to other 100 countries worldwide.

´´Brazil is a member of the Global Alliance for Sugar Trade Reform and Liberalization, which seeks to improve the world's sugar trading environment.´´

(UNICA, 2017)

Figure 1 The world largest sugarcane production in 2014 MT – 10 countries.

Country	Production (million tons)
Brazil	736,1
India	352,1
China	126,2
Thailand	103,7
Pakistan	62,8
Mexico	56,7
Colombia	36,5
Australia	30,5
Indonesia	28,6
USA	27,6

Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

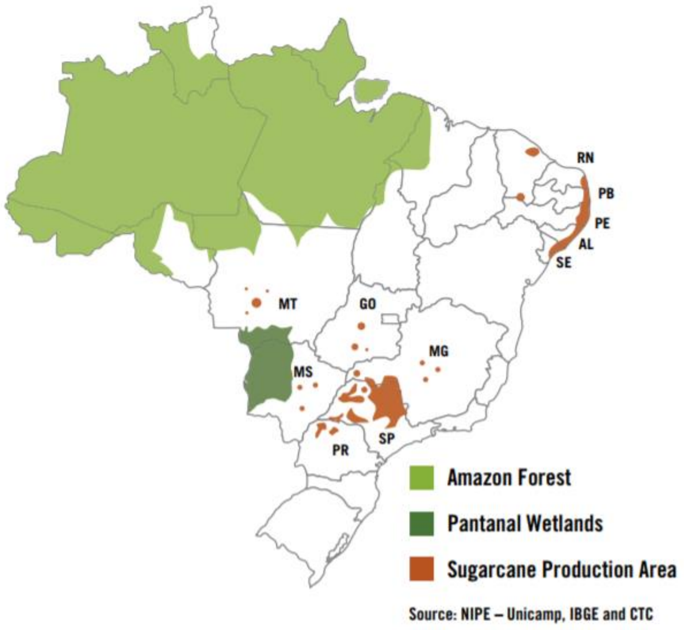
Sugarcane is mostly cultivated and produced in Latin America and Asia. Those two region are highly involved in the outcome production by 85% (Pokorna I., etc., 2011).

Sugarcane production is cultivated on 9.5 million hectares of the land. Brazil is still trying to protect the valuable areas in the country such as Amazon forest and Pantanal Wetlands[12]. There is around 4.6 million hactares used for sugarcane cultivation that is later used for bioethanol. Areas marked by brown color (Figure 2) where sugarcane is cultivated, which is according to data, 2,000 to 2,500 km far from the Amazon Forest (UNICA, 2017).

[11] Refined sugar is made from raw sugar by refining process to remove the molasses also called white sugar.

[12] Pantanal Wetlands is a natural region including the world's largest tropical wetland area.

Figure 2 Sugarcane production areas in Brazil – map.



Source. Figure retrieved from UNICA, 2017.

In European Union Single Market, there are 100 factories processing sugar of which 96 are specialising in sugar beet processing. Some of them are represented by individual private sugar factories, others are represented by alliances operating within national markets and quota systems. Factories producing sugar from sugar beet are spread through the whole Europe. The largest number of factories is in France (25), Germany (20) and Poland (18) (Maitah M., etc., 2016).

Due to Europian agrarian policy and the quota system, production has significantlly declined and the imports have increased. However, 66% of world sugar beet production is still produced in Europe (Sukova I., 2011). Sugar quota system have been recently abolished in September 30, 2017.

´´The total annual production, of about 17 million tonnes and 1,2 million tonnes of exports (2014), makes EU one among the top players in the global market.´´

(Maitah M., etc., 2016)

Sugar consumption

With growing population and consumer habits, sugar demand is increasing as well. Nevertheless, the health concerns and warnings from diet experts, how harmful sugar overconsumption might be, sugar consumption has been yet increasing. Since 1980, consumption has been increased by 70% (Cheesman, O., 2004). By 2017, the total world sugar consumption reached to 174 million tonnes per annum. As it was mentioned in chapter about sugar production above, in the same year, sugar production reached 168 million tonnes per annum. That means less than 6 million tonnes than consumption should be (Foodnet, 2017). However for five consecutive seasons the year 2015 registered the start of a sugar production deficit period (OECD/FAO, 2017).

Worldwide consumption increased by 1.6% compared to the previous economic year, while consumption in Europe declined slightly by 0.03%. Approximately 70% of all sugar produced worldwide, is consumed in the producer country (Cermak P., 2009).

The largest world sugar consumption is estimated in Asia by the economic year 2015/16. However, for the same year, white sugar production was expected to decrease by 3.9 million tonnes and total production was 59.7 million tonnes of sugar (MZe, 2016).

Table 1 Total world white sugar consumption in million tonnes (2012 – 2016).

Total World sugar consumption (million tonnes) 2012 - 2016				
Economic year	2012/13	2013/14	2014/15	2015/16
Total world consumption	155,2	161,5	164,6	167,2
thereof:				
EU	28,6	28,6	28,7	28,7
Africa	16,2	18,1	18,7	19,2
North and Central America	18,7	19,2	19,2	19,4
South Asia	19,5	19,5	19,5	19,5
Asia	70,6	74,6	76,9	78,7
Oceania	1,6	1,6	1,6	1,6

Source: Author's elaboration based on data retrieved from MZe, 2016.

According to table data for 2015/16, the total world's sugar consumption was 167.2 million tonnes, where Asia's sugar consumption was 78.7 million tonnes. It is almost half of the total sugar consumption (47.07%). The EU also takes a position with high share of consumption (28.7 million tonnes). The third largest consumer after the EU is southern Asia with stable 19.5 million tonnes in 2012 – 2016 period. Stable value of world's sugar consumption and the lowest share is in Oceania with 1.6 million tonnes during the same period.

3.2.3 Subsidy system of sugarcane in Brazil

According to data, there are around 70,000 of independent farmers in Brazil producing 40% of sugarcane processing by the millers. To be able to ensure a fair relationship between suppliers and processors, there were established sugarcane payment system in 1999. Nonprofit organisation called Consecana ensures this relationship of sugarcane and ethanol production of the state São Paulo. There are no mutual rights and responsibilities between the members.

´´Ensure the improvement of the quality evaluation system of sugarcane, carrying out studies, developing researches and promoting systematization and constant updating of the technological criteria for the evaluation of this quality.´´ (CONSECANA statute, 2017)

In order to adapt to the development of the market, rules are adjusted every 5 years. The price which is paid to sugarcane producers is proportional to their share of industrial revenue, meaning that if sugarcane production represent 60% of total sugar and ethanol production costs, sugarcane growers obtain 60% of the agro-industrial revenue. Growers obtain even more for sugar with higher sucrose content, which is determined of total raw sugar amount reduced by manufacturing process loss. The money they receive also depends on the prices of sugar and ethanol trading on the domestic and foreign market. The market price survey for Brazil is provided by Cepea[13] (UNICA, 2017).

[13] Center for Advanced Studies in Applied Economics

Other supporting program in case of sugar production in Brazil is so called RenovAção Program 2010 which helps to retrain workers that can find appropriate jobs within the sector, already have been trainned 23,000 workers (UNICA, 2017).

The only direct subsidy that is paid by Government of Brazil is *Regional Producer Subsidy*. There are no cotrols over the production amount by government, nor restriction concerning the quantity. *´´Federal Law 12,249 from June 2010 sets the value of $ 5.00 per metric tonne of sugarcane up to 10,000 metric tonnes per grower for sugarcane produced during the 2009/2010 crop.´´* It is because Brazil wants to balance the cost of the production differential between mills on the Northeast and Central sound (UNICA, 2010).

3.2.4 Summary

The history of sugar goes far B.C., used by wealthy people who used sugar as something luxurious. However, for ordinary people, this treat was almost unreachable. Nowadays sugar is produced from sugarcane or sugar beet and mostly in the loose or solid form as a white or raw sugar (brown). Sugarcane is produced in tropical areas in 120 countries whereas sugar beet is possible to cultivate in temperate regions. World total sugar production reaches up to 168 million tonnes in economic year 2015/2016. According to FAO 2016, production increase was planned to 1.7% per annum to achieve 210 million tonnes by the year 2026. Since 2000, Brazil has maintained its position as the largest producer and exporter of sugarcane in the world. Based on the FAOSTAT data information in 2014, total sugarcane production was 736.1 million tonnes thereof 37.3 million tonnes of raw sugar was produced the same year. Total sugar consumption was 164.6 million tonnes in 2014 so the difference between production and consumption was 3.4 million tonnes. Three years later in economic year 2016/2017, the sugar consumption and production increased and the difference was 3.19 million tonnes. Consumption (174 million tonnes) is going to be higher than production (170.81 million tonnes). The difference is displayed (Table 2) in red rectangles, a negative number indicates insufficient sugar production in 2017.

Table 2 Total world sugar production & consumption (2014, 2017) in million tonnes.

year	**Total world sugar production**	**Total world sugar consuption**	
2014	168	164.6	3.4
2017	170.81	174	-3.19

Source: Author's elaboration based on data retrieved from FAOSTAT, 2017 and MZe 2016.

Table 3 Total sugarcane & raw sugar production & consumption (million tonnes).

Total sugarcane production in Brazil (million tonnes)	
year	total production
2014	736.1

Total raw sugar production in Brazil (million tonnes)	
year	crop production
2014	37.3

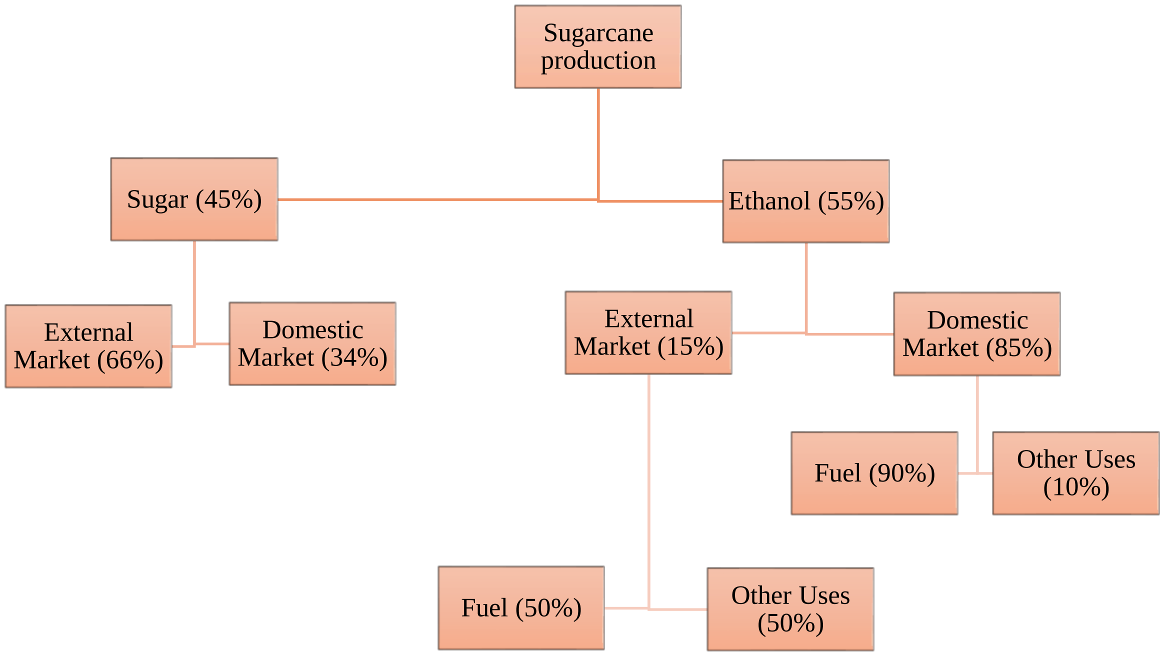
Total world sugar consumption (million tonnes)	
year	total consumption
2014	164.6

Source: Author's elaboration based on data retrieved from FAOSTAT, 2017.

Sugar is an affordable source of energy and can be well stored. Sugar demand should increase by 2% per annum by the year 2025 and in developing countries (Africa, South America, Asia) sugarcane should still stay a main crop.

Brazil use sugarcane for two main purposes – 45% of sugarcane is to produce sugar and 55% for ethanol. Both comodities are used in Domestic and External market where sugar is more used in external market while ethanol rather in domestic market, in which 90% is for fuel. All usages of sugarcane production are displayed down below (Figure 3).

Figure 3 Usages of sugarcane in Brazil in 2006.



Source: Author's elaboration based on data retrieved from UNICA, 2017.

European Union (EU) is the biggest sugar beet producer, where the European sugar market is regulated by minimum beet price, trade mechanisms and production quotas. The Sugar Quotas have been recently abolished in September 30, 2017 and this reform might have an influence on EU sugar prices in the future.

Consecana is a non profit organisation taking care of sugarcane producers and sugarcane millers, improving and strethening the sugar energy chain, helping to solve common problems and searching for sustainability of the sectors. Sugarcane growers obtain 60% of the agro-industrial revenues if sugarcane production represents 60% of total sugar and ethanol production costs.

3.3 Biofuels

3.3.1 Situation of biofuels in the EU and abroad

Transport has always been an integral part of the society. In the past, the transportation was expensive, and only a high society could afford it, mostly it was the Royal Family. Like sugar, it was an expensive and unique to own the means of transport, whether it was a horse carriage, the predecessor of today's car or an draught animal for transport or for plowing tool. One of the major factors in the usage of plant based biofuels is the economy of their production and the ability to compete with other comparable fuels (substitutes) on the market (Abrham Z., 2004).

Due to the rapidly growing population and increasing transportation requirements, there have been attempts to develop cars powered by biofuel derived from hazelnut oil in the 19^{th} century. The industrial revolution, which was from the 18^{th} century to 19^{th} century gradually switched from manual production (manufactoring) to factory mechanical mass production used new sources of energy, especially coal. It was called industrialization, and from there was not such a big step to the production of engines powered by biofuel, later by diesel fuel. The population keeps growing and diesel-powered cars are more accessible nowadays.

The total number of motorized vehicles, i.e cars, buses, lorries and commercial vehicles, is getting close to 1 billion. In the USA, the level of motorization, i.e the number of motor vehicles per 1000 inhabitants, is about 800. In the future, we are approaching the situation where there will be on average one vehicle per inhabitant (vitejtenazemi.cz, 2013).

´´The world is currently faced with two significant problems – fossil fuel depletion and environmental degradation – which are continuously being exacerbated due to increasing global energy consumption.´´

(GUPTA, R.B. and DEMIRBAS, A., 2010)

´´Human kind today faces several challenges related to hunger, environmental deterioration, and lack of energy.´´

(Bakhat M., 2013)

Alternative sources of fuel and renewable energy resources are going to play a major role in the future. By the year 2050, a population growth is projected to be 9.7 billion, and demand for energy is going to increase with population (OSN Information Centre Prague, 2017).

3.3.2 The history of biofuels

For thousands of years, people have used biofuels for domestic use. Wood and dried manure served to heat their homes, there is even mention of biogas used in China 2000 years ago. To be able to turn on the street lamps, biogas was used from the first European biogas device built in 1895 in England. However, first biogas station was built in Bombay around the year 1850. Later, at the beginning of the 20th century, the first bio-fuel engine using peanut oil, invented by the well known diesel engine inventor, Rudolf Diesel was introduced. After the First World War, in United States, biofuel was more often used (25%) for cars than petroleum (Markov S., 2016).

In 1925 brought successful 430 km long ride between the Brasilian cities São Paulo and Rio de Janeiro powered by alcohol (Hincica V., 2013). At the beginning of the 20th century, Brazilians were trying to obtain energy from alcohol. In São Paulo, students from polytechnic school were interested in using ethanol to power cars.

For instance, during and after the Second World War, in most of the European countries used cars (even personal cars) powered by so-called wood gas[14] (Appendix 1) (wood combustion) for quite a long time because of lack of gasoline. It became a massive situation during the war, in Sweden, more than 50% of all buses and more than 40% of lorries were powered by wood gas.

In 1970, 80% of Brazilian sugarcane was used for sugar as a food and only 20% was used for ethanol production. In that period, production of ethanol was increasing in Brazil. During the economic year 2005/06, 53% of sugarcane was used for ethanol production (USDA, 2006).

3.3.3 Biofuel and its species

Nowadays, forest and wood waste is mainly used for the production of heat and electricity from biomass (Abrham Z., 2004).

Biofuels were pushed back into the background at a time when oil was affordable and readily available. Nowadays, population is interested in biofuels again. Many publications and resources inform population about all possible environmental impacts that are caused by emissions on our planet and our health. Biofuels are promoted as a source of energy producing less carbon dioxide and other pollutants during combustion (ČAPPO, 2007).

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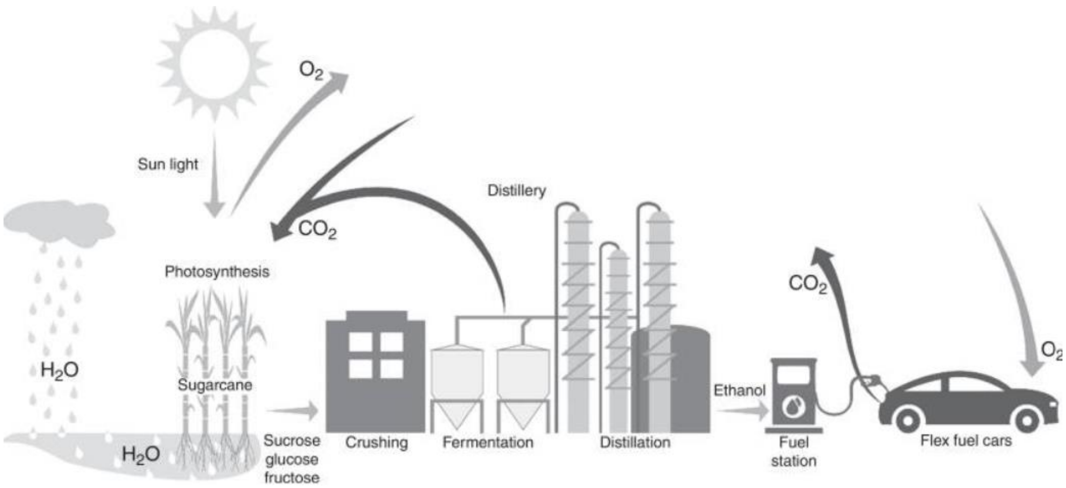
[14] Appendix 1 - a photo of what a wood gas powered car looked like in 1944.

Sugarcane ethanol is an alcohol-based fuel produced by the fermentation of sugarcane juice and molasses. Based on data it is a cost-competitive and low-carbon option holding a leading position as a renewable fuel in the transport sector offering environmental performance of any biofuel that has been produced (UNICA, 2017).

Sugarcane transforms carbon dioxide (CO_2), water (H_2O) and energy from light into sugars releasing oxygen (O_2) into atmosphere via photosynthesis. Sugarcane is harvested and crushed and the obtained sugar is fermented by yeasts and then converted to ethanol. Ethanol combustion generates CO_2 which returns to the atmosphere to close the cycle (Figure 4) (Lopes, M.L., 2016).

Figure 4 Sugarcane converting cycle to produce ethanol.



Source: Retrieved from Lopes M.L., 2016.

´´Biological feedstocks that contain appreciable amounts of sugar – or materials that can be converted into sugar, such as starch or cellulose – can be fermented to produce bioethanol.´´ (Kim S., 2004)

Biofuels are, mostly for the transport sector, produced from plant biomass or bio-waste in a liquid or gaseous form (Pandey A., 2009).

Biofuels are classified into 3 categories:

- ***First - generation biofuels***
- ***Second - generation biofuels***
- ***Third - generation biofuels***

1. *First-generation biofuels*

First-generation biofuels are nowadays used the most, including bioethanol produced from sugar or starchy crops such as grain, sugar beet, sugarcane, potato, sweet sorgum, wheat, corn, barley and higher fatty acid methyl esters (FAME)[15] obtained from rapeseed oil also from palm, sunflower or soybean (Prazak V., 2017).

FAME – Fatty acid methyl esters

´´Biodiesel fuel, which is defined as fatty acid methyl ester (FAME), is one of the most promising bioenergies used as a substitute for fossil diesel and can be produced commercially with methanol by transesterification of triglyceride, which is a major component of oils and fats in vegetables and animals.´´

(Pandey A., 2009)

Fatty acid methyl esters are mostly suitable for diesel fuels and are considered as a clean biofuel. In the Czech Republic, biofuels are understood as a bioethanol and FAME processed especially from rapeseed oil in accordance with EN 14214[16].

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[15] *´´The physical characteristics of fatty acid methyl esters are closer to those of fossil diesel fuels than pure vegetable oils, but properties depend on the type of vegetable oil. A mixture of different fatty acid methyl esters is commonly referred to as biodiesel, which is a renewable alternative fuel. FAME has physical properties similar to those of conventional diesel. It is also non-toxic and biodegradable.´´ (European Biofuels Technology Platform, 2011)*

[16] EN 14214 is a quality standard which descries requirements for the most used common type of biodiesel (FAME) published by European Committee for Standardization. (Rutz D., 2006)

Table 4 First and second generation of biodiesel.

	First - generation	**Second - generation**
Final product	FAME	FAME
Feed stock	Vegetable food oils	Vegetable oils, animal fats, Used oils, high acidity oils, non-edible oils
Technology	Alkaline transesterification	Acid esterification + transesterification (hydrocracking)
Considerations	Food vs fuel conflict	Technical, non food oils

Source: Author's elaboration based on data retrieved from Luque R. et all, 2011.

Biomass

The raw material for the production of current first generation biofuels is biomass. Biomass is a substance of biological origin. It is renewable, clean and very widespread, therefore well available. Nowadays, it contributes to world´s energy supply by 10-14% (Saxena R.C., 2009). It includes vegetal biomass, grown in soil and water (algae, trees, crops), also animal biomass (animal fertilizers), organic waste and organic production (Bridgwater A.V., 1999), stalks and grasses (RAM B. GUPTA, 2010). Biomass generally consists substances such as hydrogen[17], carbon[18], oxygen[19], nitrogen[20] and a small part of sulphur[21]. Since the biomass is organic, it also contains solar energy in its chemical bond (Demirbas A., 1999).

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[17] Hydrogen (H) is a colorless, odorless, flammable gas that combines chemically with oxygen to form water (Dictionary.com, 2017).

[18] Carbon (C) is widely distributed element that forms organic compounds in combination with hydrogen, oxygen, etc. Well known as a diamond and graphite in pure form and as a charcoal in impure form (Dictionary.com, 2017).

[19] Oxygen (O) is a colorless, odorless, gaseous element, in nature it occurs in a combined form and represents about 1/5 of the atmosphere volume (Dictionary.com, 2017).

[20] Nitrogen (N) is a colorless, odorless, gaseous element that represents about 4/5 atmosphere volume and is present in combined form in animal and vegetable tissues, especially in proteins: used mainly during production of ammonia, nitric acid, cyanide, explosives, fertilizer (Dictionary.com, 2017).

[21] Sulphur (S) is a nonmetallic element that exists in several forms, the ordinary one being a yellow rhombic crystalline solid, and that burns with a blue flame and a suffocating odor: used especially in making gunpowder and matches, in medicine (Dictionary.com, 2017).

´´Biomass comprises all the living matter present on earth.´´

(Saxena R.C., 2009)

The processing of biomass is done mainly by combustion that produces substances such as dust and gases from acid rain. Compared to other commodity such as coal, more than 90% of sulfur dioxide gets into the atmosphere by its combustion. The use of biomass has more positives, including the fact that biomass combustion is not as harmful as the combustion of mentioned, often used coal (Saxena R.C., 2009). However pros and cons of biofuels are further discussed in the designated chapter 3.4.1 Ecological aspects of biofuels, where this question is described in detail, reviewed by Saxena 2009, contain a cogent sentence quoted below.

´´Biomass is a renewable, potentially sustainable and relatively environmentally friendly source of energy.´´

(Saxena R.C., 2009)

By using different processes (thermochemical, biochemical / biological, physical and chemical transformations) it is possible to convert biomass into useful forms of energy. The amount of dry matter and water affects the processing of biomass and the way of obtaining energy from it.

Biomass transformation processes:

Thermochemical transformations rank among the dry processes and there are three types:

- ***combustion***
- ***pyrolysis***[22]
- ***gasification***

[22] Pyrolysis is the process of heat treatment of organic substances with the exclusion of access oxygen, air or other gasifying substances (Ministry of the Environment of the Czech Republic, 2010).

Biochemical transformations of biomass rank among the wet processes:

- ***alcoholic fermentation*[23]**
- ***methane fermentation*[24]**

Physical transformations of biomass are all done mechanically by:

- ***crushing***
- ***stamping***
- ***pelleting***
- ***grinding***
- ***splitting***

Chemical transformations (esterification of raw bio oils) are:

- ***composting***
- ***wastewater treatment***
- ***production of ethanol - sugar beet, grain, potatoes***
- ***oil production - oilseed rape, sunflower, flax***

(Ochodek T., 2006)

Biomass can be converted into three main types of products such as electrical/heat energy, fuel for transportation and raw materials for chemical production (Saxena R.C., 2009). It depends on the type and amount of biomass-based raw material and mainly on the required form of energy output, i.e the environmental standards, the economic conditions or the specific project factors (Pandey A., 2009). The main organic components which biomass

[23] Alcoholic fermentation is a biochemical process in which plant carbohydrates are converted to ethanol and carbon dioxide in the presence of yeast (A Dictionary of Biology, 2017).

[24] Methane fermentation and is versatile biotechnology able to convert almost all types of polymeric materials to methane and carbon dioxide under anaerobic conditions (FAO, 2016).

contains are cellulose[25], hemicellulose[26], lignin[27]. These are important for processes that produce fuel and chemicals (Bridgwater A.V., 1999).

Biodiesel

Global production of biodiesel is based on rapeseed oil *(Brassica napus)* and production reaches up to 70%. Rapeseed is the world's fourth most important crop after the cottonseed, palm seed and soyabean (Luque R. et all, 2011). Even though bioethanol is used extensively as a fuel additive, biodiesel is still the most widespread biofuels in Europe. It is formed by so-called re-esterification[28] of oils using methanol as an alcohol. To use biodiesel and its consistence (oilier), it is also necessary to adapt the engine so that its parts are not damaged, otherwise there will be increased wear and shorter engine lifetime (ČAPPO, 2007).

Nowaday's modern TDi engines do not have a problem with the burning of vegetable oils. The problem is in their transport into the engine. Vegetable oils have a higher viscosity, so the flow is worse while the pump and the associated parts of the car are more strained. Due to these problems, the cars are adjusted by an oil preheater. Vegetable oil must be heated to 70 or 80 degrees Celsius to get the same viscosity as diesel to be able to flow smoothly. Then it is possible to use vegetable oils for transport (eg. rapeseed oil is currently the cheapest in Czech Republic, about CZK 15 per liter). According to the experience of many people, consumption is slightly smaller (5-8%) (ČAPPO, 2007).

Biodiesel compared to diesel is non-toxic and is easily decomposed in the nature. After one month, 95% of biodiesel is decomposed compared to diesel's 40%. Also, the values of CO_2 released during biodiesel combustion are much lower - up to 60% (ČAPPO, 2007).

Bioethanol

Bioethanol, so-called ethyl alcohol or ethanol is a liquid that is used as a fuel or as an additive. Its high oxygen amount allows better oxidation of gasoline hydrocarbons with

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[25] Cellulose is the main constituent of the plant's and wood's cell walls, cotton, hemp, paper, etc. (Dictionary.com, 2017).

[26] Hemicellulose is any kind of gummy polysaccharides group, intermediate in complexity between sugar and cellulose, that hydrolyze to monosaccharides more readily than cellulose (Dictionary.com, 2017).

[27] Lignin is an organic substance that, with cellulose, forms the chief part of woody tissue (Dictionary.com, 2017).

[28] Esterification is a chemical reaction in which an ester is formed from an organic or inorganic acid and an alcohol (Ebewele R.O., 2010).

subsequent reduction in CO emissions and aromatic compounds. Bioethanol is the world's most used biofuel for transportation. It is more aggressive than gasoline. When using bioethanol in combustion engines (petrol and diesel engines), it is necessary to respect the specification of the fuel, make certain modifications to the engine and it also may require a special handling car regime. It is better not to let the car parked for a long time. It could cause moisture penetration into the engine, which is not good for bioethanol-powered cars (higher compatibility with water), which can cause degradation of fuel quality and may cause engine failure eventually. The largest producer is Brazil, producing 50% of bioethanol processed from sugarcane, while in the USA 95% ethanol is processed from corn (Luque R. et all, 2011). Main raw materials for ethanol production is sugar derived from sugarcane and sugar beet. By using ethanologenic fermantation[29] bioethanol is produced.

Biogas

Nowadays biogas is the least used biofuel for transport. It is mainly used to generate electricity but not as a fuel for motor vehicles. Biogas is processed by using anaerobic digestion[30] to obtain methane from biodegradable materials and wastes. Waste materials able to decompose with absence of oxygen are for instance fruit and vegetables waste. Biogas can be also generated spontaneously on municipal landfills, but otherwise has no use (Pandey A., 2009).

EU legislation

According to European legislation – Directive 2009/28/EC, the utilization of organic waste to produce biogas can lead to significant reduction in emissions greenhouse gases, and therefore has significant benefits for improving the environment.

> *[12] ´´The use of agricultural material such as manure, slurry and other animal and organic waste for biogas production has, in view of the high greenhouse gas emission*

[29] Fermentation is a change brought by a ferment, as yeast enzymes, which are able to convert grape sugar into ethyl alcohol (Dictionary.com, 2017).

[30] Anaerobic digestion is the conversion of biodegradable waste matter into compost in the absence of oxygen (Dictionary.com, 2017).

saving potential, significant environmental advantages in terms of heat and power production and its use as biofuel. Biogas installations can, as a result of their decentralised nature and the regional investment structure, contribute significantly to sustainable development in rural areas and offer farmers new income opportunities.´´ (Eur-lex, 2009)[31]

2. Second - generation biofuels

The raw material used for second generation biofuels is so-called non-food biomass, such as timber, slurry, manure, grass waste or agricultural waste (maize, rape, straw, hay), or ethanol produced from lignocellulose[32] also different BtL technologies[33] (biomass to liquid). Second-generation biofuels might be better than first-generation biofuels and therefore are used more often. Mainly due to lower costs, better greenhouse gas emissions and during the production it is possible to use a larger range of the biomass (Drahotsky I., 2003).

´´Moreover, for second-generation ethanol processes, energy balance for ethanol production from cellulosic materials is expected to be better than that of sugarcane or corn.´´ (Lopes M.L., 2016)

3. Third - generation biofuels

Water algae can be used as a food, fuel raw material for the production of hydrogen. The third - generation of biofuels is constantly evolving and a lot of hope is put into the research. Scientists believe that algae energy could produce biofuels comparable to conventional crude oil fuels in the future. Algae can produce renewable energy while absorb carbon dioxide (Algaculture[34]). After delivery of CO_2, green algae grow very quickly. If research will be successful one day and the algae can be converted to biofuel, it will be much

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[31] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance).

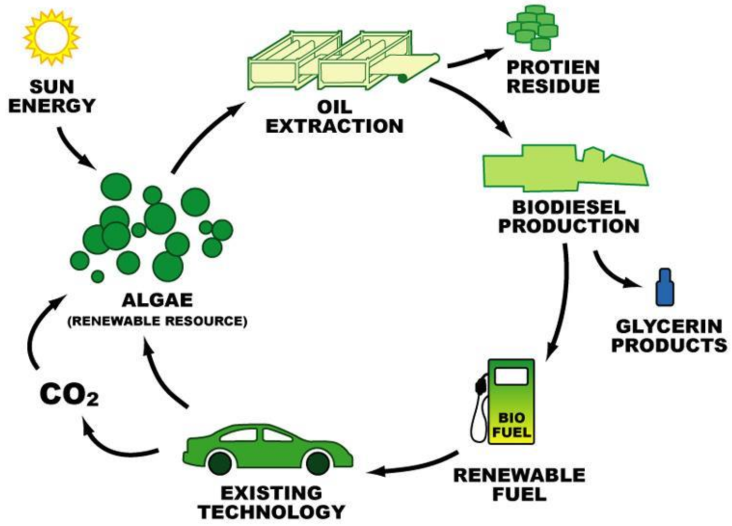
[32] Lignocellulose is any of various compounds of lignin and cellulose comprising the essential part of woody cell walls (Dictionary.com, 2017)

[33] Biomass to liquid (BtL) is a multi-stage process applied to synthetic fuels made from biomass through a thermochemical route (ETIP Bioenergy-SABS, 2017).

[34] Algaculture (farming of algae) can be a route to making vegetable oils, biodiesel, bioethanol and other biofuels (Zafar S., 2015).

more profitable per hectare than sugarcane, soya or corn according to experts. Algae can also help clean urban waste water (Dragone G., 2010). Later, this method should have a positive effect for sustainable development also by cutting CO_2 emissions by 90% compared to current transport fuels.

Figure 5 Carbon dioxide close cycle for third - generation biofuels.



Source: Retrieved from Dragone G., 2010.

3.3.4 Biofuel production and consumption in Brazil

As it was mentioned earlier, Brazil has become a leader in renewable energy already in 1970s. Brazil uses more than 40% of its energy from renewable sources. Comparing to other countries around the world using around 15%. Main source of Brazilian renewable energy is sugarcane which provides almost 17% of total country's needs. The highest share has category oil and derivates with 37.3% of total. Hydroelectricity also has a high share in Brazil, being the second-largest producer of hydroelectricity in the world after Canada[35] (Appendix 2) (UNICA, 2017).

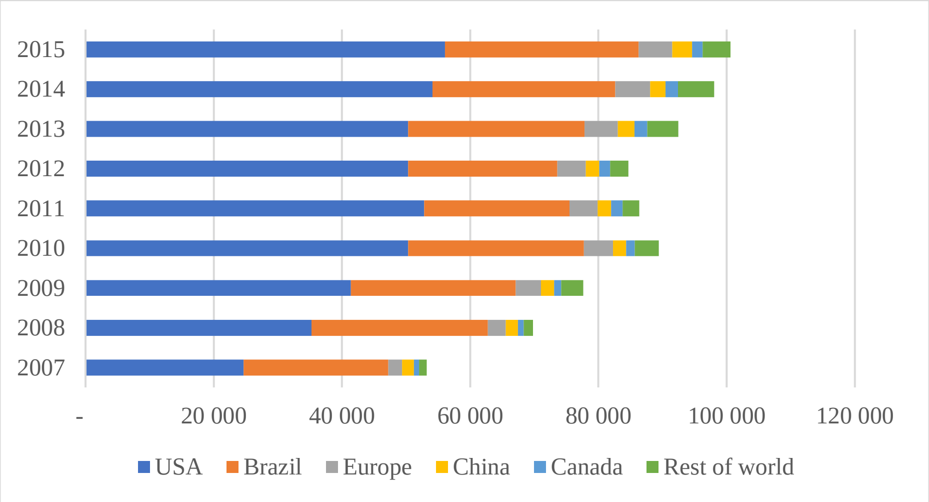
Brazil together with the USA are the biggest producers of ethanol in the world. In 2005, it was around 35% of global production which was 4.2 billion gallons of ethanol. Nowadays Brazil produces 50% of world fuel ethanol using sugarcane and molasses (by-

[35] Brazilian Energy Matrix (Appendix 2)

product of sugar mills). While the USA produces 95% of ethanol from corn, Canada uses less efficient crops such as wheat, barley and corn for bioethanol production. Less efficient means that for ethanol production made from wheat, more feedstock is needed (3.6 hl/t[36]) than for example from sugar beet (1 hl/t) (GUPTA, R.B., 2010).

Graph 4 is defining world total ethanol production in period 2007 – 2015, proving that USA and Brazil were the leaders in ethanol production in this period. Total world ethanol production in 2007, after all value summarization, was equal to 53.202 thousands m^3 comparing to the year 2015 where the production increased significantly to 100.599 thousands m^3.

Graph 4 World Fuel Ethanol Production by Country in period 2007 – 2015 (thous. m^3).



Source: Author's elaboration based on data retrieved from RFA, 2017.

In the Table 5 below, production is directed to Brazil showing available data for the economic year 2016/17 where the total ethanol production in Brazil is estimated to 27.254 thousands m^3, which is less than was noted back in previous year 2013/2014.

[36] 1 hectolitre = 100 litres

Table 5 Total ethanol production in 2007 - 2017 period in Brazil (thousands m^3).

Total Fuel Ethanol Production in period 2007 - 2017 in Brazil.	
year	total production
2007/2008	22.527
2008/2009	27.526
2009/2010	25.691
2010/2011	27.376
2011/2012	22.682
2012/2013	23.226
2013/2014	27.476
2014/2015	28.481
2015/2016	30.232
2016/2017	27.254

Source: Author's elaboration based on data retrieved from UNICA, 2017.

Brazil estimated producing cost of sugarcane ethanol to $0.81 per gallon (USDA, 2006). Summary down below defines what the total cost of ethanol are composed of to reach the total value (Table 6).

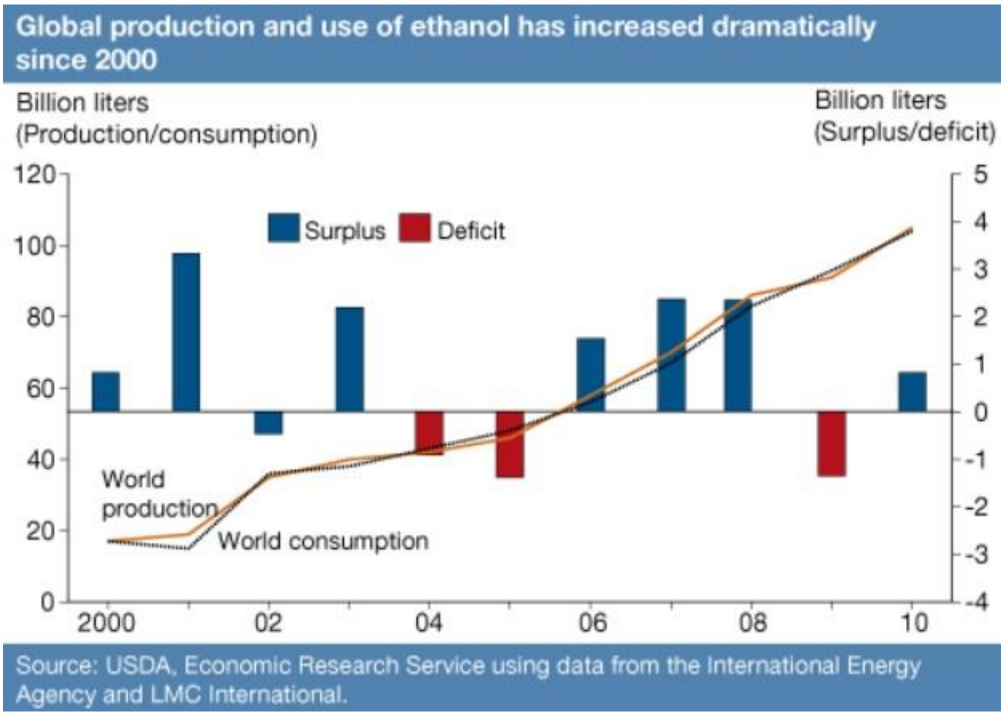
Table 6 Summary of estimated ethanol production costs (dollars per gallon) – Brazil.

Ethanol production costs	
Cost item	Brazil sugarcane
Feedstock cost	0.3
Processing costs	0.51
Total costs	0.81

Source: Author's elaboration based on data retrieved from USDA, 2006.

Not only total world ethanol production and its use has rapidly increased since 2000, but also the sugarcane production (from 4.3 million hectares in 1990, to over 10 million hectares in 2010). As it was mentioned in previous chapter, ethanol demand was mostly driven by increased world crude oil prices in recent years.

Picture 1 Global production and use of ethanol has increased dramatically since 2000.



Source: Retrieved from USDA, 2016.

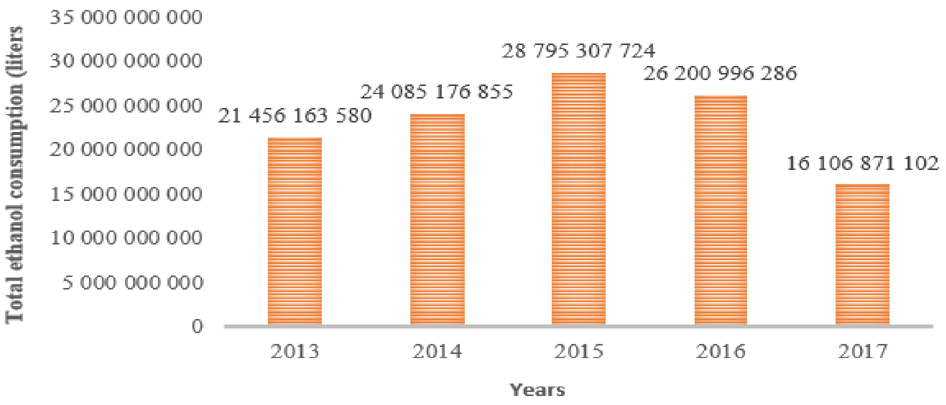
The use of ethanol is also due to the environmental issue (ethanol is environmentally friendly fuel over crude oil), ethanol belongs to renewable sources and the government of many countries tries to reduce dependence on those that are not renewable, such as crude oil. Brazil as the world's second largest ethanol producer and exporter should maintain the development of the ethanol sector to meet global demand. Since sugarcane is the main raw material for ethanol production, there is a need to increase its production, as well as the supportive government policy during the production process. In 2010, sugarcane production harvested in Brazil, used for ethanol production has been 55.4% (398 million tonnes) of total sugarcane harvest (USDA, 2016).

Total ethanol consumption

Brazil is one of the main countries that use ethanol for fuel consumption on a large scale. In 2016, consumption reached to 26.2 billion liters which assumed consumption in 2017 to be slightly higher. The total ethanol consumption forecast for the year 2017 was 27.7

billion liters. In the Graph 5 below is recording consumption for year 2017, but the data is not yet sufficient, due to the last recorded data was in August. Compared to the previous year 2015 where the total consumption was higher by 2.7 billion liters. According to USDA, it happend because of current recession in the economy and expected negative growth of Brazilian GDP for 2016. Decisions of consumers are driven by relations between ethanol and gasoline prices (USDA, 2016).

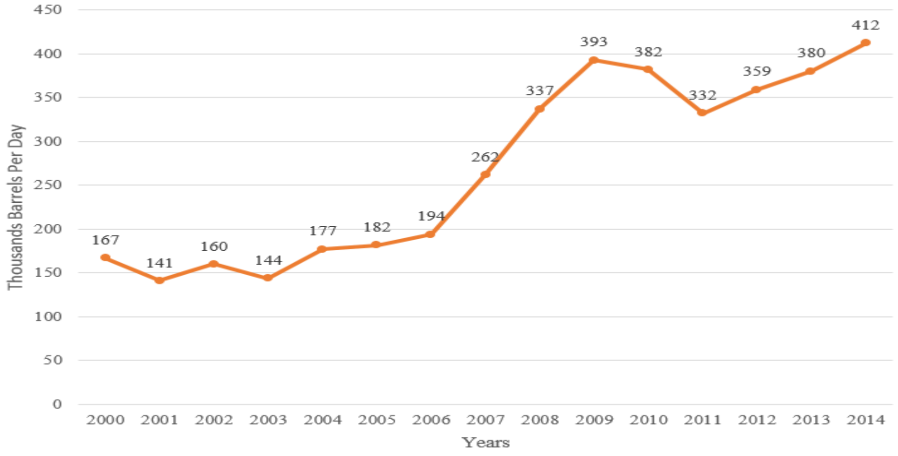
Graph 5 Total Fuel Consumption in period 2013 - 2017 in Brazil (liters).



Source: Author's elaboration based on data retrieved from UNICA, 2017.

Ethanol consumption per day in Brazil (Graph 6) was the highest in the year 2014 with 412 thousand barrels. According to data, the decrease in consumption in 2011 was to 332 thousand barrels per day and since on the consumption has been increasing.

Graph 6 Ethanol consumption per day in period 2000 – 2016.



Source: Author's elaboration based on data retrieved from Knoema, 2017.

3.3.5 Subsidy system of bioethanol in Brazil

´´In developed and developing countries facing fluctuations of oil prices, the improvementof energy security and supply is increasingly becoming a fundamental reason for implementing biofuels policies.´´

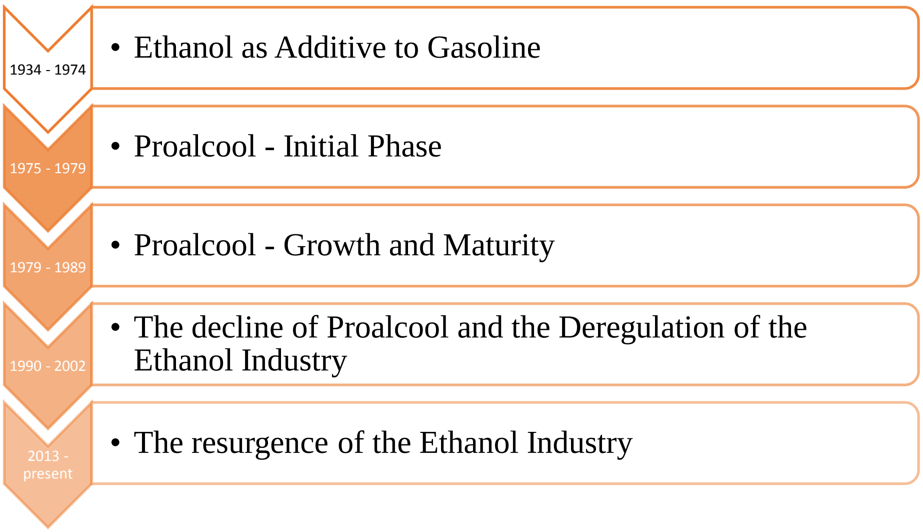
(Luque R. et all, 2011)

In 1975, The Brazilian National Ethanol Program, describes the basics of biofuels policy, was established by the Brazilian government. Sugarcane ethanol was increased in the year 2003 just after Flex Fuel Vehicles (FFV) was introduced. Drivers had a choice at filling station, as these types of vehicles are able to go on 100% ethanol, gasoline or any other mixture of these two. This option may have price and environmental benefits for the drivers. In 2012 was represented 92% of new Flex Fuel Vehicles that was sold in Brazil. This has made a possibility to include flex fuel motorcycles and buses running on ethanol. Number of FFV in Brazil has reached up to 24 million (UNICA, 2017).

´´Since the 1990s, the government of Brazil (GOB) has had no direct control over the volume of ethanol produced, consumed domestically, or exported. GOB has also abolished any type of price control during the aforementioned period. However, the GOB can influence ethanol production and price setting through the ethanol-use mandate and tax incentive measures.´´ (UNICA, 2015)

Brazilian government increased federal taxes on gasoline to $0,22/liter in 2015. This fact has increased the competiveness of ethanol relative to the fossil fuel. To be able to stimulate ethanol consumption, some of the Brazilian states decreased tax for ethanol and increased the state tax on gasoline circulation of goods and services. In the same year the government also permited enhancing blending ethanol for gasoline from previous 25% to 27% (UNICA, 2015). Figure 6 is decribing the systematic use of ethanol from sugarcane for fuel purposes in Brazil 1934 – present - Historical perspective.

Figure 6 Systematic use of ethanol from sugarcane for fuel purposes in Brazil.



Source: Data retrieved from UNICA, 2010 – Biofuels Annual .

1. **Ethanol as Additive to Gasoline (1934 – 1974)**

In this period, ethanol was converted to anhydrous ethanol to be blended with gasoline. Sugar and Ethanol Institute was created to regulate the activity of ethanol blended to gasoline, which became obligatory.

2. **Proálcool – Initial Phase (1975 – 1979**)

After the oil shock (1970's), Brazilian government accepted plan to guarantee the country's energy independence. In 1975, National Alcohol Program (Proálcool) was established, which objective was to decrease dependency on oil imports by promoting the production of anhydrous ethanol as an additive to gasoline.

3. **Proálcool – Growth and Maturity (1979 – 1989)**

Based on second oil crisis, the second phase of Proalcool started by setting new goals, for instance, to take ethanol as substitute and not as additive to gasline by expansion of sugarcane fields to produce hydrated ethanol as fuel.

4. **The decline of Proálcool and the Deregulation of the Ethanol Industry (1990 – 2002)**

In 1986, the price of oil decreased and with the recovery of sugar prices in the international market, production of ethanol was unsuitable and created problem on the market such as sales of ethanol – fueled cars.

5. **The resurgence of the Ethanol Industry (2003 – present)**

During this period, Flex Fuel Vehicles were developed and produced, so the drivers could have an option to choose fuel they prefere. It is either 75% gasoline and 25% ethanol or even 100% ethanol as a legacy of Proálcool to promote ethanol use.

3.3.6 Summary

´´Globally, reducing our dependency on fossil fuels while maintaining a safe and healthy environment is a high priority.´´ (Nass, L. L., et.all, 2007)

Nowadays, the world is dealing with two very important problems. Based on mentioned research papers, those two things that are affecting negatively the world are fossil fuel depletion and environmental degradation. One of the solutions might be starting to use biofuels on large scale and to explore further researches for using renewable sources more. Biofuels are mostly used for transport sector. The largest sugarcane production is located in Brazil and is also suitable commodity to produce ethanol. Raw material to produce ethanol is biomass which is produced by burning biological materials to generate heat. Modifications of biomass can be different - mechanical (grinding, crushing), chemical, thermochemical, mechanical-chemical or biochemical (combustion, pyrolysis, anaerobic fermentation, gasification, pressing). Biomass is nowaday used for production of first generation biofuels. Other two categories are second - generation biofuels which are generetad from non – food biomass such as timber, manure, agricultural waste and third - generation biofuels which are still in deep research where scientist are trying to use algae for producing biofuels. Second - generation biofuels, based on data, might be better than first-generation due to lower costs, better greenhouse gas emissions and because the biomass is made from raw materials that are no longer usable for food or feed production (Appendix 3)[37].

Brazil uses mostly energy from renewable sources more than 40% which includes oil, sugarcane, natural gas, hygroelectricity, wood and vegetal coal (Appendix 2). The world's total ethanol production is still increasing (in 2015 it was 30,232 thousands m^3) and holds the second position behind the USA (in 2015 it was 56,045 thousands m^3). By the economic year 2016/ 2017, ethanol production forecast is 27,254 which might be 3 thousand m^3 less

[37] The distribution of biofuels and the use of biomass (Appendix 3)

then previous year 2015/2016. Brazil has also high share of total ethanol consumption. For the year 2016, it was 26.2 billion liters and it was assumed that in 2017 it will be sligtly higher up to 27.7 billion liters.

3.4 Environmental aspects of sugar and biofuels

3.4.1 Ecological aspects of biofuel production and impact on the environment

As already mentioned before, during the industrial development (last two centuries), demand for fossil fuels has gradually increased and this has led to a higher carbon dioxide concentration discharged into the atmosphere. For instance, by combustion of 1kg of diesel fuel it releases 3.12 kg of CO_2, much more than by combustion of coal, however less than by combustion of gas (Ochodek T., 2006).

According to Brazilian Sugarcane Industry Association, sugarcane ethanol is a clean and affordable renewable fuel. This association is describing all possitive effects in study published in 2017 that sugarcane ethanol has significant reduction of GHG emissions, helps diversify energy supplies respecting the environment. Brazil is the world's biggest producer of sugarcane ethanol. Sugarcane ethanol cut CO_2 by 90% in 2003 avoiding 290 million tonnes. It can be also used as a biodiversity of energy - bioeletricity and biohydrocarbons called Biomass to liquid (BtL). It also contributes to economic growth and creates rural jobs (UNICA, 2017).

´´Sugarcane ethanol has emerged as a leading renewable fuel in the transport sector. All gasoline sold in Brazil includes a blend of 18 to 25% ethanol. ´´ (UNICA, 2017)

Non-governmental and environmental organizations are expressing negative reaction to intensive use of biofuels in the transport, emphasizing that biofuel production itself can be harmful. According to their concerns, the reasons are: food production is being replaced by the biofuels production, for example in Brazil it leads to food price increase for the inhabitants; there also might be a negative ecological impact on plantations; used chemicals for production might have harmful effects on health and the environment; biofuel production consumes more energy than it contains (Drahotsky I., 2003). There were arguments about land use for biofuels feedstock versus land used for food production in 2008 by The International Centre for Trade and Sustainable Development. Increasing food prices should not automatically influence poor people, however it should be reflected as an income for farmers in developing countries (Luque R., 2011).

Based on the handbook, biofuels are considered as renewable sources together with solar power, hydroelectricity, wind power, geothermal power and tidal power (Pandey A., 2009).

´´Renewable energy is the energy derived from resources that are regenerative or, for all practical purposes, cannot be depleted. ´´

(Pandey A., 2009)

According to citation above, biofuels are apparently diferent from fossil fuels. Lower production of greenhouse gases or pollutants during combustion makes developers think and continue with research and enhance biofuels development. Fosil fuels are the world's biggest environmental pollutant (Pandey A., 2009).

EU situation

After the accession of the Czech Republic to the EU, surplus of agricultural land was expected, which would not have been applicable to food production. One of the paths of rational land use is to use it for energetic and industrial crops (Abrham Z., 2004).

According to the Directive 2009/30/EC by European Parliament and the Council *´´The Community has committed itself under the Kyoto Protocol to greenhouse gas emission targets for the period 2008-2012. The Community has also committed itself by 2020 to a 30 % reduction in greenhouse gas emissions in the context of a global agreement and a 20 % reduction unilaterally. All sectors will need to contribute to these goals.´´ (Eur-lex 2009)*[38] community has committed to reduce greenhouse gas emmission by 30% until 2020.

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[38] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC (Text with EEA relevance)

Kyoto Protocol

An effort to progressively reduce greenhouse gases was reflected in a protocol adopted in 1997. Kyoto Protocol (to the United Nations Framework Convention on Climate Change), is an international agreement where countries committed by the end of the first commitment period (2008 - 2012), to reduce greenhouse gas emissions by at least 5.2% comparing to 1990 (Table 7). In December 2012, the amendment has been approved for the continuation of the Kyoto protocol for another eight years (2013 - 2020). The reduction is related to emissions such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrogenated hydrogen fluoride (HFCs), polyfluorocarbon (PFCs), sulfur hexafluoride (SF_6) and nitrous fluoride (NF_3).

Table 7 States and their reduction targets set.

Reduction targets	**States**
8%	EU countries - Belgium, the Czech Republic, Denmark, Finland, France, Ireland, Italy, Liechtenstein, Luxembourg, the Netherlands, Germany Portugal, Austria, Greece, Slovakia, Slovenia, Spain, Sweden, Bulgaria, Estonia, Lithuania, Latvia, Hungary, Romania, United States of America, Switzerland
7%	USA
6%	Japan, Canada, Hungary, Poland
5%	Croatia
0%	New Zealand, Russian federation, Ukraine
-1%	Norway
-8%	Australia
-10%	Iceland

Source: Author's elaboration based on data retrieved from Kyoto Protocol, Annex B, 1997 data and Ministry of the Environment of the Czech Republic, 2017.

The Kyoto Protocol also enables commitments to be fulfilled through so-called *flexible mechanisms*. These mechanisms might allow countries the possibility of securing emissions reductions in the territory of another country, or to purchase the right to emit greenhouse gases from another state (UNFCCC, 2005).

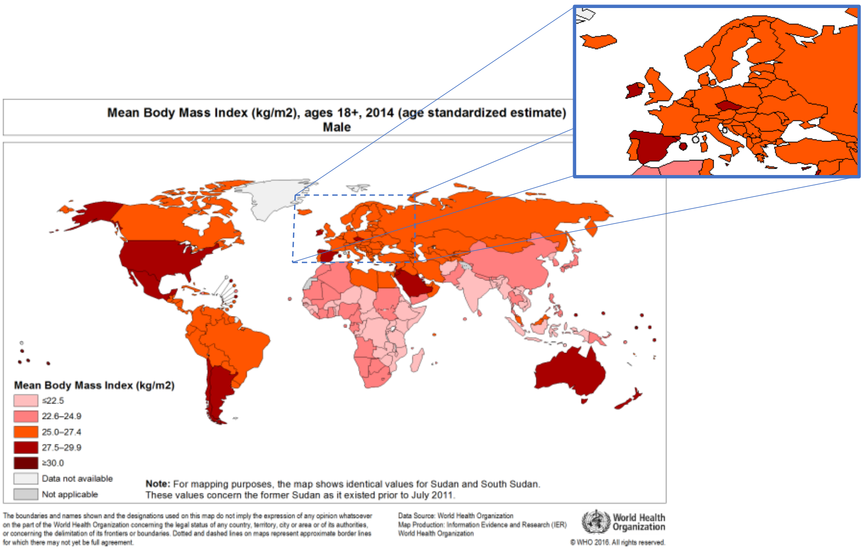
3.4.2 Ecological aspects of sugar production and impact on the environment

3.4.3 Sugar from the health perspective

World Health Organization (WHO) offers data and statistics about obesity and overweight that are more than disturbing. These two terms might contribute to serious health problems. Generally well known health problems are cardiovascular diseases (heart disease), diabetes (WHO, 2016), high blood pressure (hypertension) and high cholesterol, infertility, asthma (Harvard School of Public Health, 2016) and strokes (Deangelo L., 2017).
Obesity and overweight is measured by global method Body Mass Index (BMI). With BMI measuring method, it is obvious that obesity and overweight are not the same conditions. BMI is calculated by a person's weight in kilograms divided by the square of his height in meters (kg/m^2). Overweighted individual has BMI greater than or equal to 25 and BMI for obesity is greater than or equal to 30 (WTO, 2016). Since 1980, obesity has more than doubled worldwide. In 2014, more than 1.9 billion 18+ adults (39%) were overweight and of these over 13% (600 million) were obese.

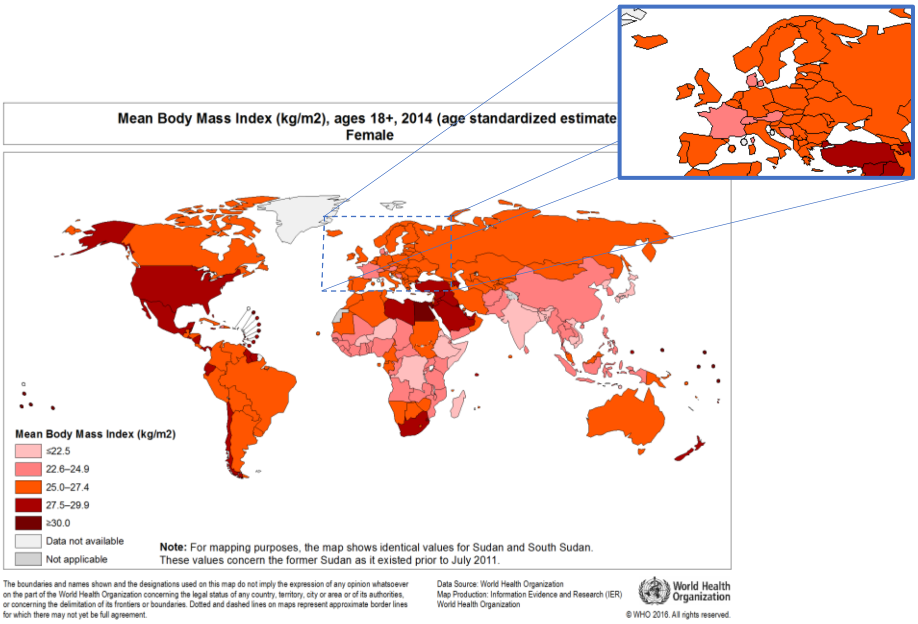
Body Mass Index of male and female worlwide in 2014, highlight countries are the most affected by obesity and overweight inhabitants. (Figure 7 and Figure 8) Countries with high BMI (between 25.0 - 29.9) are USA, Alaska, Mexico, Argentina, Chile, Spain, Czech Republic, Saudi Arabia, Australia, Ireland, Canada, Europe, Latin America, Russia, Libya, Egypt, Ecuador and South Africa. In most countries women are more obese than men but according to data, male obesity is growing faster. Brazil maintained the same index as for women and men's obesity (25-27.4). In comparison with the Czech Republic, it can be said that men had higher index (27.5 - 29.9) than women in 2014 (OECD, 2017).

Figure 7 Mean Body Mass Index, ages 18+, 2014, Male.



Source: Retrieved from WHO, 2016.

Figure 8 Mean Body Mass Index, ages 18+, 2014, Female.



Source: Retrieved from WHO, 2016.

Annually, 168 million tonnes of sugar, is produced in the world (Foodnet, 2017). In 2006, world sugar production was 147.8 million tonnes (Javurkova J., 2006), in 2008 it was 150 million tonnes (Sukova I., 2011). Sugar consumption in the world is growing and is slightly different in individual countries. Total world sugar consumption should reach to 174 million tonnes per annum in 2017. That means that production is lagging demand about 5.9 million tonnes less. The ranges among sugar consumption in countries might be between 7 - 66 kg per capita. In EU countries consumption is around 30 kg per person (Sukova I., 2011).

The highest sugar consumption is in Brazil with around 60kg sugar per capita as well as the highest sugar production (38.63 million tonnes per annum).

People nowadays consume too much food and drinks containing a high proportion of sugar. American Heart Association recommends 25 grams of sugar (6 teaspoon) per day for women, 38 grams (9 teaspoons) for men and for children 12 - 25 grams (3 - 6 teaspoon) depending on their age and caloric needs (Johnson R.K., 2009). The World Health Organization (WHO) recommends daily intake no more than 10% of an adult's calories. The best would be if 5% of the daily sugar intake comes from natural sugars in fruit, honey and syrups. For a diet contain 2,000 calories, 5% would be 25 grams.

´´In both adults and children, WHO recommends reducing the intake of free sugars to less than 10% of total energy intake.´´ (World Health Organization, 2015)

According to previous publication there has been no evidence of harm by reducing the intake of sugars to less than 5% of total energy intake which is around 25 grams and that is equal to 6 teaspoons per day.

For instance, Americans consumes 82 grams per day, one teaspoon of sugar is equal to 4 grams which means they consume 20.5 of teaspoons with sugar, more than three times more that is recommended (Ervin R.B., 2013).

Sugar is added nearly to everything because of its sweet taste that attracts the attention of the consumers and improve the taste of food especially for children. High amount of sugar can affect the body same way as a taking drug. When food is eaten people need eat more and more which can be really harmfull for the body.

Based on research, obesity is preventable (Edwards C., 2016). People are being taught since childhood to consume sugar and they are familiar that what is sweet is also tasty. Unfortunately, they are no longer familiar with what high sugar intake can cause to their body.

´´Most consumers seem to have limited nutrition knowledge.´´ (Parmenter K., 1999)

According to Swiss research, 2/3 of study participants believed that brown sugar is less harmful than white sugar or even healthier (Dickson-Spillmann, Siegrist, & Keller., 2011) For many, it might be great disappointment to find out that brown sugar is simply white sugar mixed with molasses. Molasses contain vitamins and minerals but it is also high on sugar contain, therefore the excess of sugar can be harmful for body as well as white sugar. Sugar intake is still mostly associated with unhealthy weight gain and dental caries, so there can be direct relationship - no sugar intake, no obesity.

´´Sugar has hit the headlines in recent years because of health fears, with accusations and counter-claims that too much sugar and fat in people's diets contribute to a growing 'obesity epidemic'. However, despite these warnings, the demand for sugar has continued to rise steadily, increasing by about 70% in total since 1980.´´ (Cheesman O., 2004)

However, it is necessary to highlight that a certain amount of sugar is desired for maintaining healthy balanced diet (World Health Organization, 2015).

4 Practical part

4.1 Influences that affect the world sugar and ethanol prices

Sugar

In countries where sugar is produced, the government have high influence on sugar prices. Sugar is one of the most difficult commodities to trade with, mostly due to government's issues minimum fair prices, agrarian policies, import duties, ethanol mandates to sustain local market and export subsidies. Every country has its own sugar subsidies and interventions (Commodity basis, 2014). Sugar has been the aim of interventions earlier in many countries and this situation continues to. Sugar market has been influenced by demand and supply (Cermak P., 2009).

The world sugar prices are also affected by the overproduction of sugar. In the case of sugar overproduction, sugar prices are relatively low for consumers. Decreasing sugar prices are also affected by forecasts of global sugar consumption. While the sugar production is increasing not only that creates possible surpluses of sugar as a future stock, which itself will reduce the price of sugar but also with decreasing sugar consumption, this effect is even more intense, sugar prices are lower. However due to the health aspects discussed in the chapter 3.4.2, in recent years the demand is decreasing in developed countries but grow more in developing countries. Sugar consumption is mainly affected by household incomes and the price of alternative sweeteners.

Brazil, India and China which are stressed in Figure 1 are countries with the highest sugarcane production in the world. Because of the sugarcane fields location in Brazil, the price of sugar is highly affected by the weather. A climate without frost and with sufficient rainfall during the season is important for the sugarcane growth therefore any deviation can affect the sugar production, for instance Brazilian's great drought in the past. Same as the drought can be harmful pests and diseases (Cermak P., 2009). Sugar traders are monitoring also effects such as crises and government regulation in those specific countries that might influence sugar prices as well. Regulations are typical especially for USA and EU.

Ethanol

Increasing demand for alternative fuel such as bioethanol with highest production in Brazil is influenced by increasing oil prices and that might cause sugar price increases.

Therefore the more ethanol will be used, the more the price of oil will be affected by the price of sugar (Esmaeili A. et. all, 2011).

´´The sugar market played a primary role in driving the ethanol growth within and outside the country.´´

(Luque R., 2011)

4.2 Analysis of the price development of sugar in the last 10 years

4.2.1 Sugar price development in the world

Sugar is one of the oldest traded commodity in the world with high influence in economies and politics. Currently, sugar is the most regulated commodity by quotas, subsidies and import duties in almost every country. World sugar consumption is still growing and sugar market is significantly influenced by prices that can be more or less different. Sugar prices are usually displaying in USD (OECD/FAO, 2016).

Nowadays there are two basic types of sugar (white and raw sugar) that are traded on Commodity Exchange. It is the place where demand, meet supply. The most important Commodity Exchanges are in London and New York. The price of white sugar in London Exchange is expressed in USD per tonne while one contract[39] is 50 tonnes. In US the price is expressed in US cents per pound (1 pound = 0.45kg) and one contract is same as in London Exchange 50kg (112 000 lb) (Cermak P., 2009).

World sugar price in 2008/2009 was around 0.28 USD/kg while in other countries such as Argentina and India the sugar prices were 0.51 USD/kg or sugar price in Japan reach to 2.2 USD per kg (Sukova I., 2011). In 2014, the international sugar prices drop down about 30%. Due to the forecast of the global sugar deficit at the beginning of the season, it led to a increasing the sugar prices around 2% in 2015. Sugar prices are expected to increase only for few years as a consequence of high level of stocks and low oil prices. World sugar production will cover growing demand that is why it doesn't increase that much. In 2025 the forecast of the international raw sugar price is projected to be USD 342 per tonne and the

[39] Future contracts are financial derivatives under which contracting parties commit to buy or sell a given quantity of commodities towards certain date for a predetermined price. That means the parties do not trade with a physical commodities, only with the promise to delivery a certain commodity to the second parties represented by future contracts (Cermak P., 2009).

same projection of white sugar is to be USD 425 per tonne. There exists a difference between white/refined and raw sugar prices and that is called white sugar premium which temporarily decreased in 2017, for instance the declining was also in EU with raw sugar import after quota abolition (OECD/FAO, 2016). São Paulo is the state of the Brazil, produce around 60% of sugarcane. The most of the sugarcane (90%) is cultivated in south-central Brazil (Figure 1). More than 50% of sugarcane in Brazil is located afterwards into ethanol production thus the sugarcane prices are not related to sugar prices. After the sugarcane is harvested the first use goes to ethanol production due to faster earnings (necessary for for instance to pay off bills to suppliers) (Commodity basis, 2014).

4.2.2 Food Price Index (FFPI)

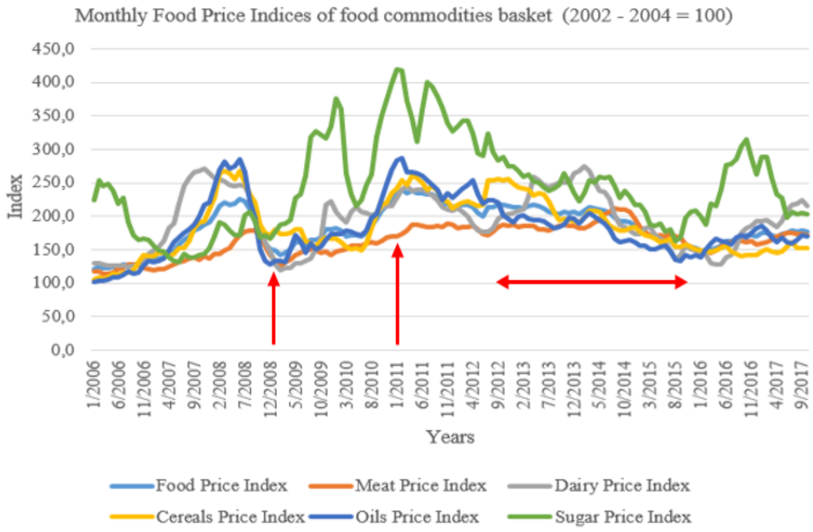
According to Food and Agriculture Organization the Food Price Index (FFPI) introduced in 1996 is measuring the mothly change in international prices of a food commodities basket including cereals, vegetable oils, dairy products, meat and sugar. It was established to help monitoring development in the global agricultural commodity market.

Average of price indices these five commodities are weighted with the average export shares of each of the groups for 2002 – 2004 (FAO, 2017).

The first food price peak was in 2008, mainly due to a high oil prices, adverse weather condition caused low harvest, the exchange rate of dollar and increased biofuel usage. Based on studies including opinions that there have been created new correlation between oil and food products because of biofuel, while oil prices peaks are relocated into commodity market. During last years, this possible relation between mentioned commodities has been discussed a lot in topics such as energy and agricultural economics. The question is, if and how the food commodities prices are linked to oil prices, while it seems that biofuels plays a role in it as well. There has been evidence over time that the number of food product prices are increasing while are connected to crude oil (Bakhat M., 2013).

Gaph 7 displays Monthly Food Price Indices of Food Commodities Basket in period 2006 – 2017 (values for year 2017 are estimated, but it should be close to these data) however in the graph is shown the first spike in 2008, after this year price of commodities rapidly increased, highest shift was with sugar. Sugar price index in 2008 was 181.6 while in the end of the economic year 2010 sugar price index increased by 41.68% to 257.3. After four years of steady declined (2012 – 2016) Food Price Index started to increase again, which is already third consecutive rise. However, not all commodities are going the same direction, the increase was reflected in dairy, oils, sugar and meat.

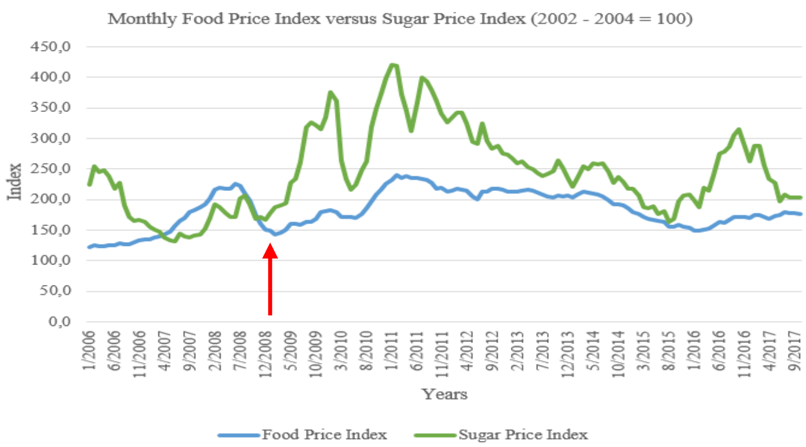
Graph 7 Monthly Food Price Indices of Food Commodities Basket (2006 – 2017).



Source: Author's elaboration based on data retrieved from FAO, 2017.

Monthly Food Price Index according to Sugar Price Index since the year 2006 until October of still continuing year 2017, where the average Sugar Price Index reached to 202.8 points (Graph 8). In the October 2006 the Price Index (165.2) was lower by 37.6 points higher than in 2017. Sugar price index has started steadily increasing in 2008 due to first price peak according to previous data.

Graph 8 Monthly Food Price Index versus Sugar Price Index in period 2006 – 2017.



Source: Author's elaboration based on data retrieved from FAO, 2017.

4.3 Analysis of the price development of biofuel in the last 10 years

4.3.1 Biofuel price development in the world

As it was mentioned in theoretical part of this thesis, due to rising demand for transport energy, where the expectation of demand increase is about 60% by the year 2030, it is very much needed to find an alternative source which would replace the oil while reducing high rates of growing GHG emissions (transport sector represents 20% global CO_2 emissions). To find the solution is also needed because of monthly fluctuating oil prices in developed and developing countries. That is the reason of improving the energy security and implementing the biofuels policies. If the trade of oil commodities enhance the intensity, it creates trade imbalance, and for instance Japan or USA, European Union, India and China are dependent on import (Luque R., 2011). Ethanol production is more profitable with higher oil prices and this is big opportunity for many countries.

4.3.2 Biofuel price development in Brazil

In 1973, was the first oil crisis and Brazil decided to established the earlier mentioned Proálcool Program in 1975. The Brazilian government has demanded a blending ratio of ethanol for the entire gasoline. This was accomplished by credit guarantees, subsidies to ethanol producers, low-interest loans for construction of new plants, and storage credit to millers. Ethanol prices are set at the levels relative to gasoline which caused higher ethanol production and consumption in the country (Tokgoz S., 2006).

Second oil crisis was in 1979, at that time the ethanol was very attractive for consumers because of reducing ethanol taxes, few years later in 1986 there were built new vehicles (76%) that ran for ethanol. In 1990s, consumers reduced the use of ethanol as a fuel due to lack of ethanol in the country and also stopped purchasing cars designed for that purpose. Therefore there was no regulation over ethanol industry until 1999 together with abolished price supervision (Tokgoz S., 2006).

As it was described in chapter 3.3.5 the FFVs were introduced in 2003 which helped to ethanol industry in Brazil.

4.4 Econometric modelling

This part is mainly focused on the correlation of the sugarcane prices and ethanol production in the last 18 years and its related indicators. Correlation is expressed by econometric model with two equations. First equation, targeted on the sugarcane price with regarding variables, while the second equation is focused on ethanol production which is influenced by production aspects (sugarcane production) or economic aspects (crude oil price, sugarcane price). Both equations in the econometric model should include a unit vector as well as the stochastic variable (u_1, u_2). Specification of all variables, their units and types used for econometric models are describe down below (Table 8).

4.4.1 Specification of econometric model

The economic model:

$y_1 = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7)$

$y_2 = f(y_1, x_8, x_9, x_{10}, x_7)$

Stochastic equations structure of econometric model

$$y_{1t} = \gamma_{11} x_{1t} + \gamma_{12} x_{2t} + \gamma_{13} x_{3t} + \gamma_{14} x_{4t} + \gamma_{15} x_{5t} + \gamma_{16} x_{6t} + \gamma_{17} x_{7t} + u_{1t} \quad (1)$$

$$y_{2t} = \beta_{21} x_{1t} + \gamma_{21} x_{1t} + \gamma_{28} x_{8t} + \gamma_{29} x_{9t} + \gamma_{30} x_{10t} + \gamma_{27} x_{7t} + u_{2t} \quad (2)$$

Specification of all variables, their units and types used for econometric model:

Table 8 Declaration of used variables.

Variable	Type of variable	Indication	Units of measurement
Sugarcane price in Brazil	endogenous (β)	y_1	in US$ per pound
Ethanol production in Brazil		y_2	in million gallons
Unit vector, intercept		x_1	
Sugarcane export in Brazil	exogenous (γ)	x_2	in 10 million tonnes
Sugarcane harvested area in Brazil		x_3	in 10 million ha
Crude oil price – global		x_4	average annual in US$ per gallon
Ethanol price in São Paulo		x_5	in US$ per million liters
Sugar production in Brazil		x_6	in 10 million tonnes
Number of cars powered by biofuels in Brazil – Flex fuel vehicles		x_8	pcs
Crude oil consumption in Brazil		x_9	in liters
Crude oil price – global		x_{10}	average annual in US$ per gallon
Time vector		x_7	

Source: Author's elaboration based on retrieved data.

Declaration of variables:

y_1 Sugarcane price in Brazil (in US$ per tonne)

y_2 Ethanol production in Brazil (in million gallons[40])

x_1 Unit vector, intercept (UV)

x_2 Sugarcane export in Brazil (in 10 million tonnes)

x_3 Sugarcane harvested area in Brazil (in 10 million ha)

x_4 Crude oil price – global (average annual in US$ per gallon)

x_5 Ethanol price – São Paulo (US$ per million liters)

x_6 Sugarcane production in Brazil (in 10 million tonnes)

x_7 Time vector

x_8 Number of cars powered by biofuels in Brazil – Flex fuel vehicles[41] (pcs)

x_9 Crude oil consumption in Brazil (in liters)

x_{10} Crude oil price – global (average annual in US$ per gallon)

---

[40] 1 US gallon = 3.78541178 liters

[41] Flex refers to flex fuel vehicles that can run on ethanol, straight gasoline or any mixture of these two.

Data set for 1st equation:

Year	y_1	x_2	x_3	x_4	x_5	x_6	x_7
2000	10.00	0.72	0.48	30.30	9.13	32.61	1
2001	11.00	1.23	0.50	25.95	9.54	34.43	2
2002	9.00	1.47	0.51	26.12	10.28	36.44	3
2003	10.00	1.42	0.54	31.12	11.87	39.60	4
2004	10.00	1.74	0.56	41.44	12.65	41.52	5
2005	13.00	2.00	0.58	56.49	12.98	42.30	6
2006	18.00	2.08	0.64	66.02	13.56	47.74	7
2007	19.00	2.13	0.71	72.32	14.23	54.97	8
2008	17.00	2.15	0.81	99.57	14.90	64.53	9
2009	19.00	2.68	0.86	61.65	13.99	69.16	10
2010	24.00	3.09	0.91	79.40	14.54	71.75	11
2011	31.00	2.80	0.96	94.87	15.93	73.40	12
2012	32.00	2.68	0.97	94.11	14.67	72.11	13
2013	30.00	2.99	1.02	97.91	14.35	76.81	14
2014	27.00	2.66	1.04	93.26	15.58	73.61	15
2015	19.00	2.65	1.01	48.69	15.27	75.03	16
2016	21.00	3.19	1.02	43.14	20.60	76.87	17
2017	21.00	3.16	1.05	50.88	21.34	79.87	18

Source: All data retrieved from UNICA[42], 2017; FAOSTAT[43], 2017; ABEGAS[44], 2017; STATISTA[45], 2017; and USDA, 2017.

[42] Brazilian Sugarcane Industry Association

[43] Food and griculture Organization of the United Nations

[44] The Brazilian Association of Piped Gas Distributors

[45] The Statistic Portal

Data set for2nd equation:

Year	y_2	y_1	x_8	x_9	x_{10}	x_7
2000	4002	10.00	1500980	15 725 035 974	30.30	1
2001	4037	11.00	1704480	19 225 015 474	25.95	2
2002	4878	9.00	1800980	20 250 012 913	26.12	3
2003	5036	10.00	1900200	22 784 455 934	31.12	4
2004	5040	10.00	1900340	21 163 127 876	41.44	5
2005	4998	13.00	1800980	24 725 035 974	56.49	6
2006	5001	18.00	2000030	22 435 075 423	66.02	7
2007	5 019	19.00	2003090	25 794 036 934	72.32	8
2008	6 472	17.00	2329247	27 728 075 271	99.57	9
2009	6 578	19.00	2652298	26 327 038 974	61.65	10
2010	6 922	24.00	2876173	26 225 065 477	79.40	11
2011	5 573	31.00	2848071	27 565 033 879	94.87	12
2012	5 577	32.00	3162874	30 545 038 772	94.11	13
2013	6 267	30.00.	3169111	31 725 035 974	97.91	14
2014	6 190	27.00	2940508	33 273 185 105	93.26	15
2015	7 093	19.00	2194020	30 204 833 351	48.69	16
2016	7997	21.00	1750750	31 403 929 768	43.14	17
2017	8096	21.00	1927187	32 229 158 378	50.88	18

Source: All data retrieved from UNICA[46],2017; FAOSTAT[47], 2017; ABEGAS[48], 2017; and STATISTA[49], 2017.

[46] Brazilian Sugarcane Industry Association

[47] Food and griculture Organization of the United Nations

[48] The Brazilian Association of Piped Gas Distributors

[49] The Statistic Portal

Economic assumptions:

All data set information, used for 1st equation, are available above, in data set tables. Data were retrieved from these sources: UNICA, 2017; FAOSTAT, 2017; ABEGAS, 2017; InflationData.com, 2017) STATISTA, 2017 and USDA, 2017.

The Econometric model consists of 2 stochastic equations with random variable (u_{1t} – u_{2t}), 2 endogenous and 8 exogenous variables.

To determine the dependences between variables it is used coefficient of determination, denoted R^2 or r^2. This determination is used in statistical model, where main purpose is either the prediction of future outcomes or the testing of hypotheses based on other related information.

Simply says, from how many percent the dependent variable is explained by independent variables changes in the econometric model. In statistics, a perfect positive correlation is represented by 1, while 0 indicates no correlation and negative 1 indicates a perfect negative correlation (Eberly College of Science, 2018).

- ***First equation***

Economic assumption for the first equation is that, the endogenous variable[50] (y_1) Sugarcane price in Brazil is explained by exogenous variable[51] (x_2) Sugarcane export in Brazil, (x_3) Sugarcane harvested area in Brazil, (x_4) Crude oil price – global, (x_5) Ethanol price - São Paulo and (x_6) Sugar production in Brazil. In this case it is assumed, that if one of the exogenous variables (explanatory variables) has change, the endgenous variable (explained variable) will change as well.

The basic economic model assumptions are thus as follow:

- Increase in Sugarcane export in Brazil, causes increase in Sugarcane price in Brazil.
- Increase in Sugarcane harvested area in Brazil, causes decrease in Sugarcane price in Brazil.
- Increase in Crude oil price – global, causes increase in Sugarcane price in Brazil.
- Increase in Ethanol price - São Paulo, causes increase in Sugarcane price in Brazil.
- Increase in Sugarcane production in Brazil, causes decrease in Sugarcane price in Brazil.

---

[50] Endogenous variable is a variable whose value is determined by means of independent variables, coefficients, and absolute members (Engle R.F., 1983).

[51] Exogenous variable is a variable whose values are determined outside the model system and which influences the system; input variable (Engle R.F., 1983).

- ***Second equation***

While for the second equation, the endogenous variable is (y_2) Ethanol production in Brazil explained by (y_1) Sugarcane price in Brazil, (x_8) Number of cars powered by biofuels in Brazil, (x_9) Crude oil consumption in Brazil and (x_{10}) Crude oil price – global. And as with the first equation, where is also a positive correlation[52] between variables, if one of the explanatory variables change, the explained variable change as well.

The basic economic model assumptions are thus as follow:

- Increase in Sugarcane price in Brazil, causes decrease in Ethanol production in Brazil.
- Increase in Number of cars powered by biofuels in Brazil, causes increase in Ethanol production in Brazil.
- Increase in Crude oil consumption in Brazil, causes decrease in Ethanol production in Brazil.
- Increase in Crude oil price – global, causes increase in Ethanol production in Brazil.

Dependence between selected variables

Dependence between selected variables is displayed in Graphs 9, 11, 13, 15, 17, 19, 21, 23 and 25. All data are retrieved from Data sets for 1st and 2nd equation.

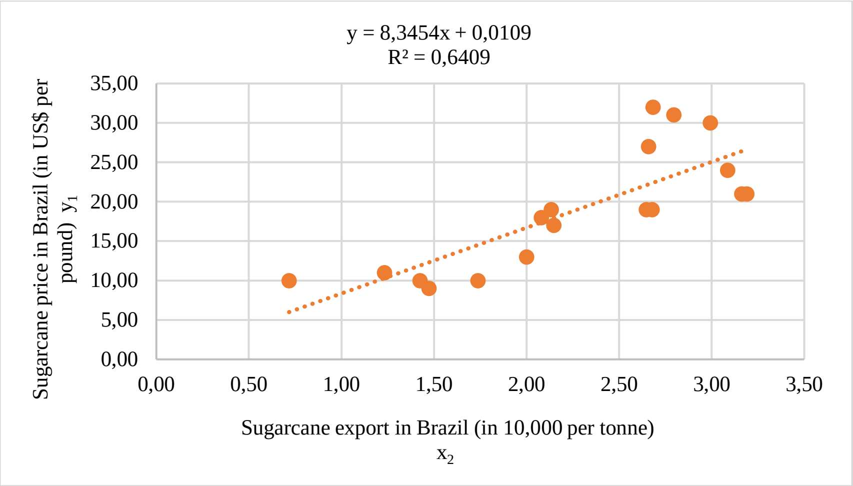
The graphs 10, 12, 14, 16, 18, 20, 22, 24 and graph 26 estimate trends between endogenous and exogenous variable over a given time period (2000 – 2017).

[52] A positive correlation exists when one variable decreases as the other variable decreases, or one variable increases while the other increases (Investopedia, 2018).

Description of graph 9 and 10

Graph 9, decribes the dependence between endogenous variable (y_1) Sugarcane price in Brazil and exogenous variable Sugarcane export in Brazil (x_2). The Coefficient of Determination indicate that there is high dependence (64.09%) between these two variables. Any change in in explanatory variable Sugarcane export in Brazil should have an impact on endogenous variable Sugarcane price in Brazil.

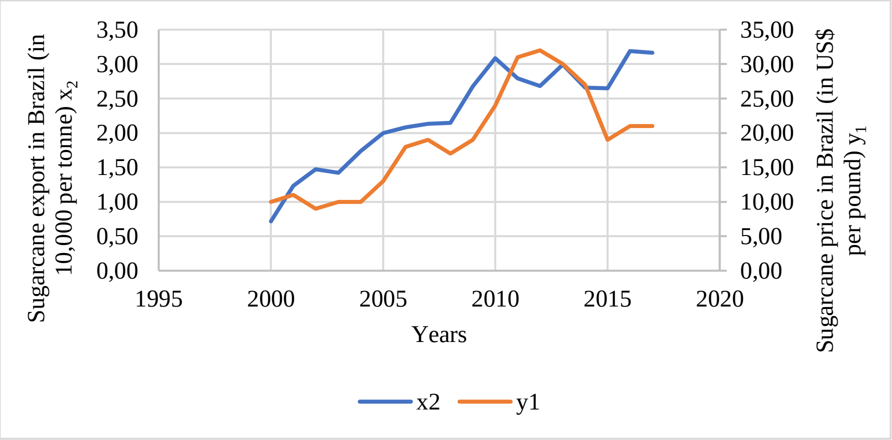
Graph 9 Dependence between Sugarcane price and export in Brazil.



Source: Author's elaboration based on retrieved data from UNICA, 2017 and FAOSTAT, 2017.

Graph 10, illustrates the Sugarcane price and export trends over a given time period (2000 - 2017). According to the chart it is seen that both variables are developing with increasing tendency until 2011, when sugarcane prices have steadily increased sugarcane exports declined and the connection occured again in 2013.

Graph 10 Sugarcane price & export trends in time period (2000 – 2017).

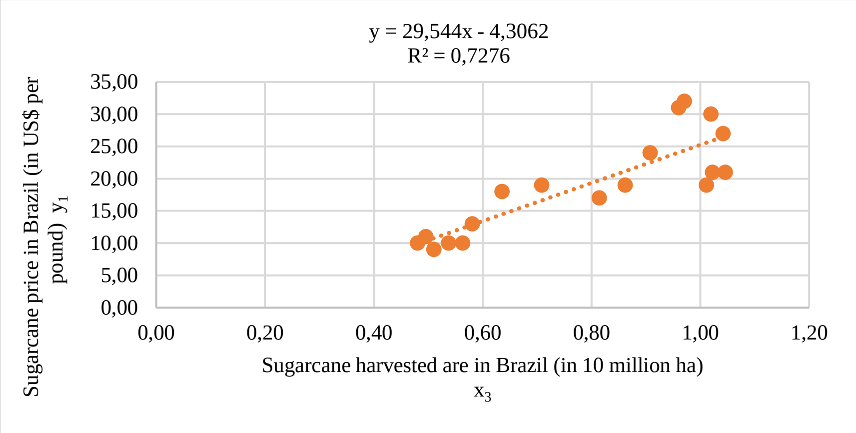


Source: Author's elaboration based on retrieved data from UNICA, 2017 and FAOSTAT, 2017.

Description of graph 11 and 12

Graph 11, displays the dependence between endogenous variable (y_1) Sugarcane price in Brazil and exogenous variable (x_3) Sugarcane harvested area in Brazil. The dependence is slightly higher (72.76%) then in previous (Graph 9) which means, dependence is higher and with changing the sugarcane harvested area in Brazil, it will have high impact on sugarcane price as well.

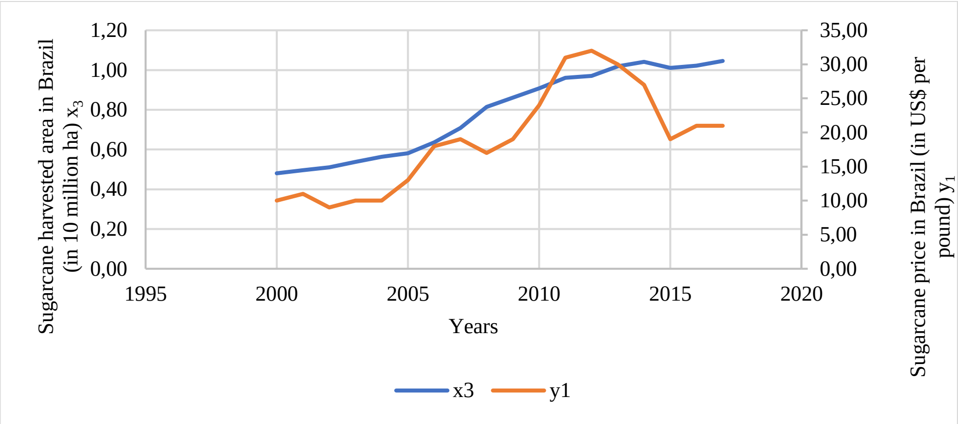
Graph 11 Dependence between Sugarcane price and harvested area in Brazil.



Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

Also positive tendencies displayed in graph 12, illustrates the Sugarcane price and harvested area over a given time period (2000 - 2017). The highest peak was in 2012, since then the sugarcane prices has started to slowly decreasing but the values of sugarcane harvested area were relatively constant.

Graph 12 Sugarcane price & harvested area trends in time period (2000 – 2017).

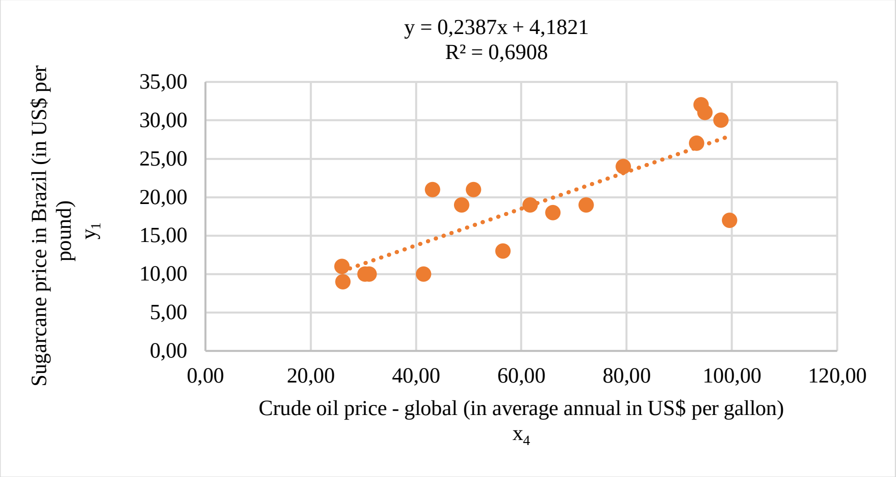


Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

Description of graph 13 and 14

Graph 13, displays the dependence between endogenous variable (y_1) Sugarcane price in Brazil and exogenous variable (x_4), Crude oil price – global. Dependence is a slightly higher (69.08%) than with the sugarcane export, but not as high as the explanatory variable sugarcane harvested area. If there will be change in oil price, there will be change in sugarcane price in Brazil.

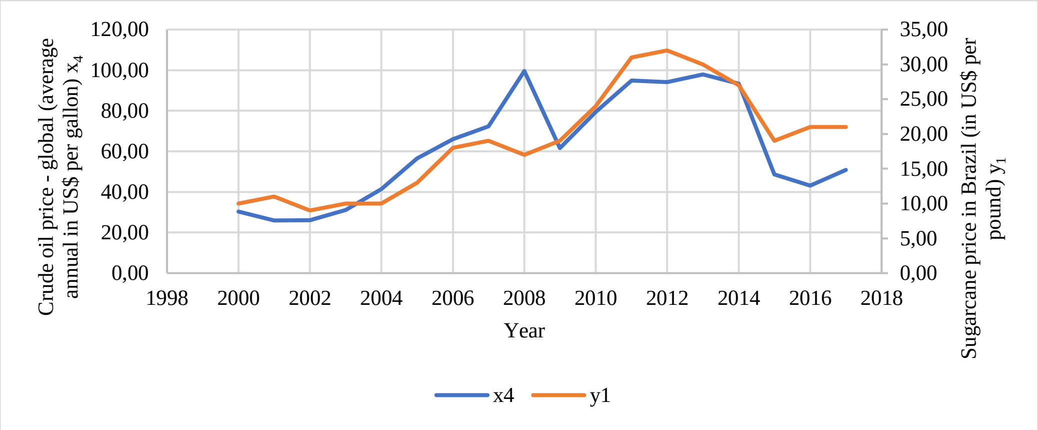
Graph 13 Dependence between Sugarcane in Brazil and Crude oil price global.



Source: Author's elaboration based on retrieved data from FAOSTAT, 2017 and InflationData.com, 2017.

Graph 14, displays the Sugarcane price and Crude oil price over a given time period (2000 - 2017). The highest decline of oil price was in 2009, since then the sugarcane prices as well as the oil price has been gradually increasing.

Graph 14 Sugarcane price & Crude oil price trends in time period (2000 – 2017).

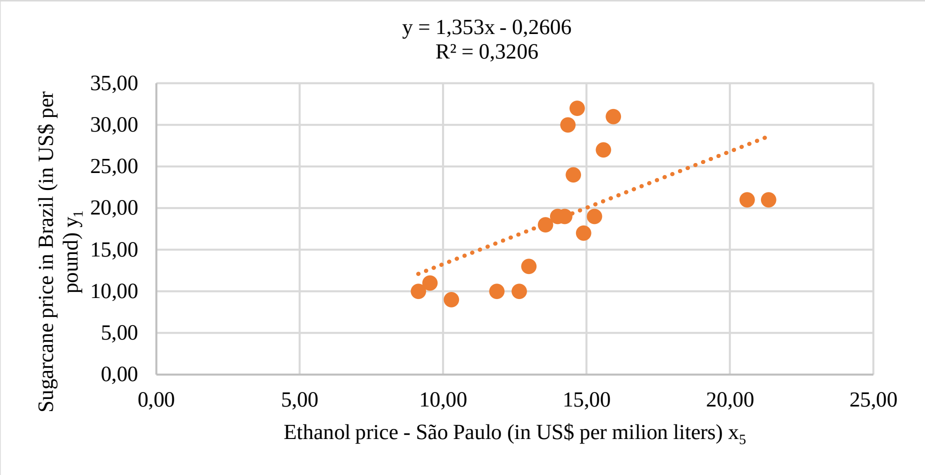


Source: Author's elaboration based on retrieved data from FAOSTAT, 2017 and InflationData.com, 2017.

Description of graph 15 and 16

Graph 15, displays the dependence between endogenous variable (y_1) Sugarcane price in Brazil and exogenous variable (x_5), Ethanol price - São Paulo. The dependence between sugarcane price and ethanol consumption (32.06%) which is signifying higher dependency, if there would be change in ethanol consumption it will affect the Sugarcane price in Brazil.

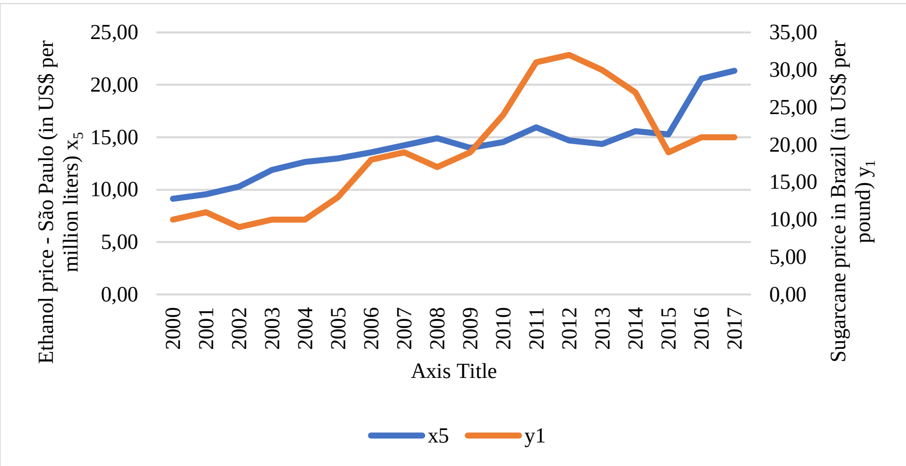
Graph 15 Dependence between Sugarcane price and Ethanol price in Brazil.



Source: Author's elaboration based on retrieved data from FAOSTAT, 2017 and USDA, 2017.

As the dependence was estimated in graph 15, graph 16 is showing interesting data for dependency on the Sugarcane price in Brazil during the last 18 years. In the year 2011 the sugarcane price has exceeded and the ethanol price stayed constant.

Graph 16 Sugarcane price & Ethanol price trends in a time period (2000 – 2017).

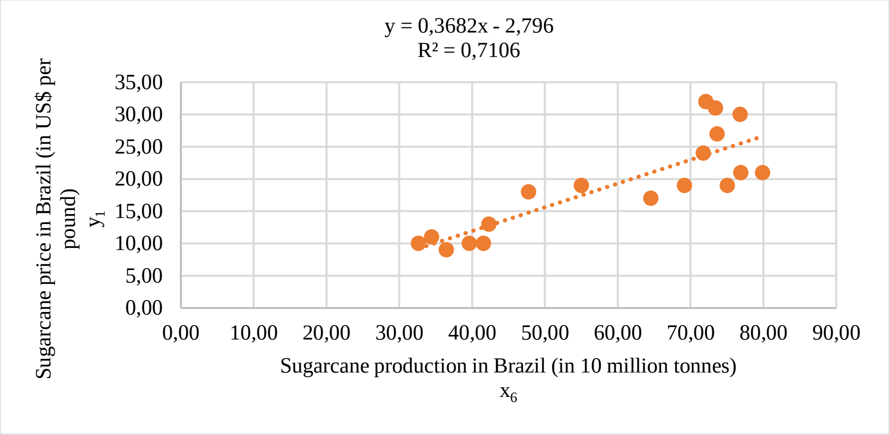


Source: Author's elaboration based on retrieved data from USDA, 2017 and FAOSTAT, 2017.

Description of graph 17 and 18

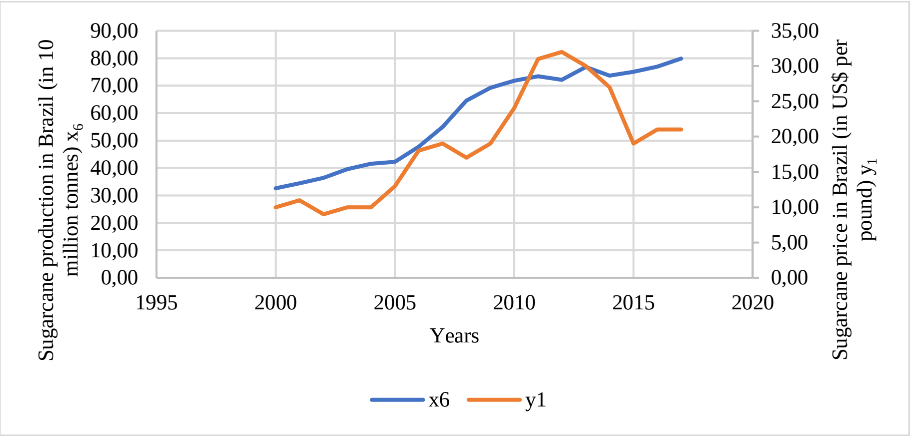
Graph 17, displays the dependence between endogenous variable (y_1) Sugarcane price in Brazil and exogenous variable (x_6), Sugarcane production in Brazil. According to calculation, the correlation reaches up to 71.06%, indicating higher dependence between variables, sugarcane production has higher dependence on sugarcane prices in Brazil and any change would cause change in sugarcane prices either positive or negative. Sugarcane harvested area with higher dependency (72.76%) is higher than dependency between variables y_1 and x_6. These two dependencies are taking the position of the highest dependency in the model of first equation. Graph 18 expresses the slow increasing of both variables over time.

Graph 17 Dependence between Sugarcane price & Production in Brazil.



Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

Graph 18 Sugarcane price & production trends in time period (2000 – 2017).

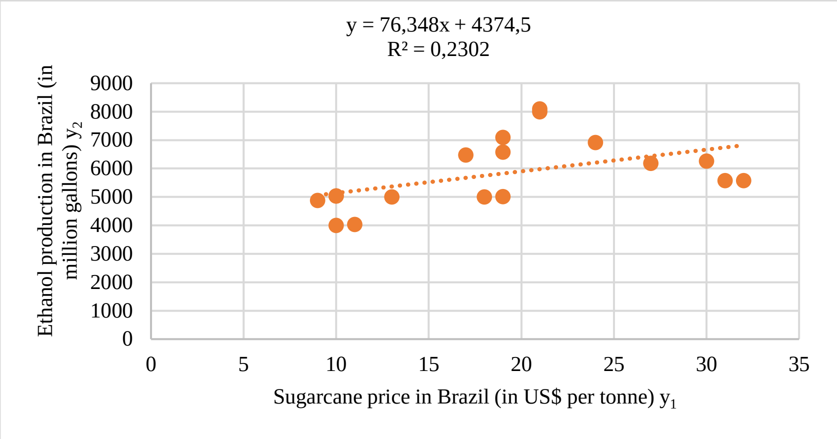


Source: Author's elaboration based on retrieved data from FAOSTAT, 2017.

Description of graph 19 and 20

Graph 19, displays the dependence between endogenous variable from the second equation (y_2) Ethanol production in Brazil and endogenous variable (y_1), Sugarcane price in Brazil, from the first equation. Changes in this variable will cause small change in Ethanol production in Brazil by 23.02%.

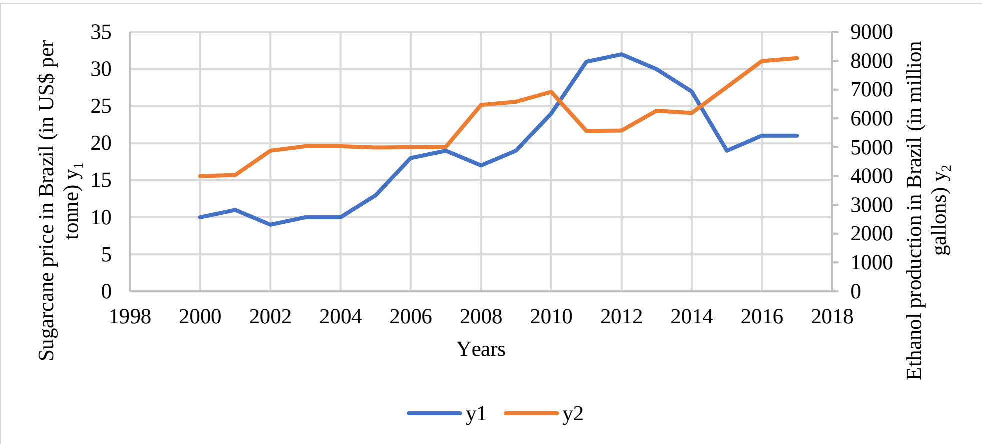
Graph 19 Dependence between Ethanol production & Sugarcane price in Brazil.



Source: Author's elaboration based on retrieved data from UNICA, 2017 and FAOSTAT, 2017.

Also positive tendencies displayed in graph 20, it illustrates the Ethanol production and Sugarcane price over a given time period (2000 - 2017). During the years 2010 until 2015 there has been steep growth of sugarcane price, however ethanol production has fallen rapidly. In 2015 values turned upside down, where sugarcane prices started to rise again and ethanol production slowly started to decline.

Graph 20 Sugarcane price & Ethanol production trends in time period (2000 – 2017).

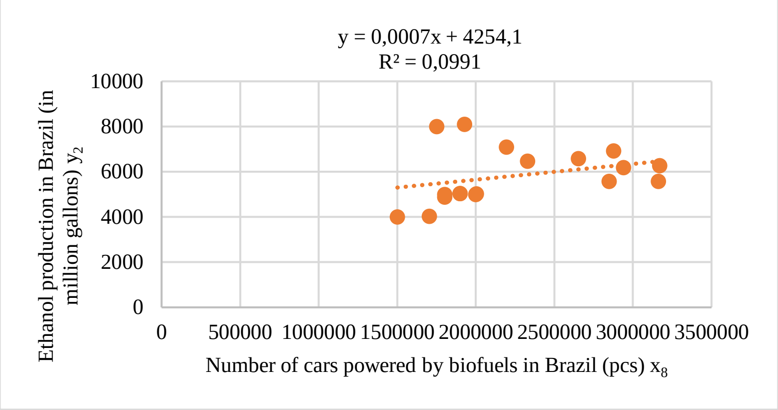


Source: Author's elaboration based on retrieved data from UNICA, 2017 and FAOSTAT, 2017.

Description of graph 21 and 22

Graph 21, displays the dependence between endogenous variable from the second equation (y_2) Ethanol production in Brazil and exogenous variable (x_8), Number of cars powered by biofuels in Brazil. Changes in these exogenous variable, will make a small change in Ethanol production in Brazil with 9.91%.

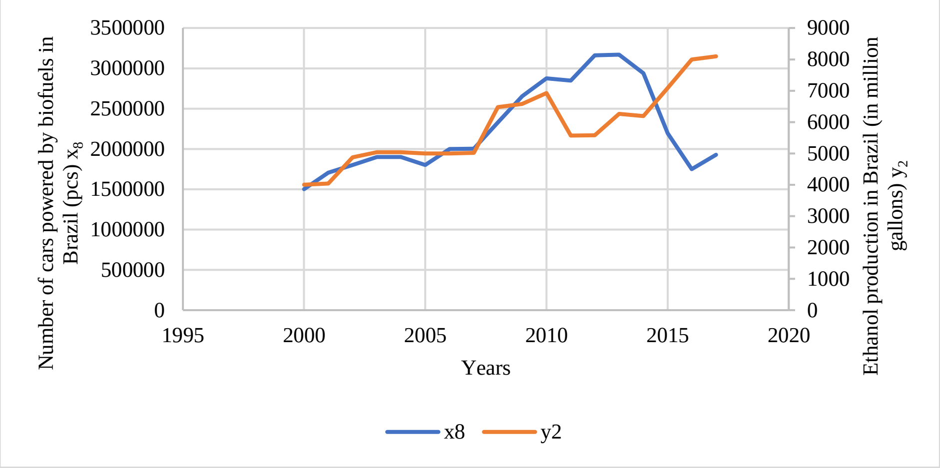
Graph 21 Dependence between Ethanol production & Biofuel cars in Brazil.



Source: Author's elaboration based on retrieved data from UNICA, 2017.

Number of cars powered by biofuels as well as the ethanol production has been slowly increasing during years 2000 – 2010 (Graph 22). In 2010 there has been steep growth of number of cars powered by biofuels while the ethanol production has been decreasing.

Graph 22 Ethanol production & Biofuels cars trends in time period (2000 - 2017).

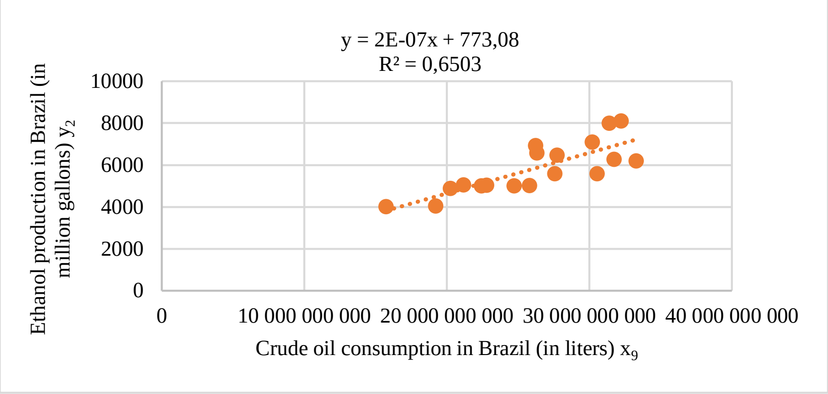


Source: Author's elaboration based on retrieved data from UNICA, 2017.

Description of graph 23 and 24

In the graph 23, there is displayed the dependence between endogenous variable from the second equation (y_2) Ethanol production in Brazil and exogenous variable (x_9), Crude oil consumption in Brazil. Dependence 65.03% signifying, that crude oil consumption has relatively high influence on Ethanol production in Brazil, if there is a change in Crude oil consumption, there will be a high change in Ethanol production. Among the other explanatory variables (x_8) and (x_{10}), variable (x_9) has the highest dependence towards explained variable (y_2) Ethanol production in Brazil.

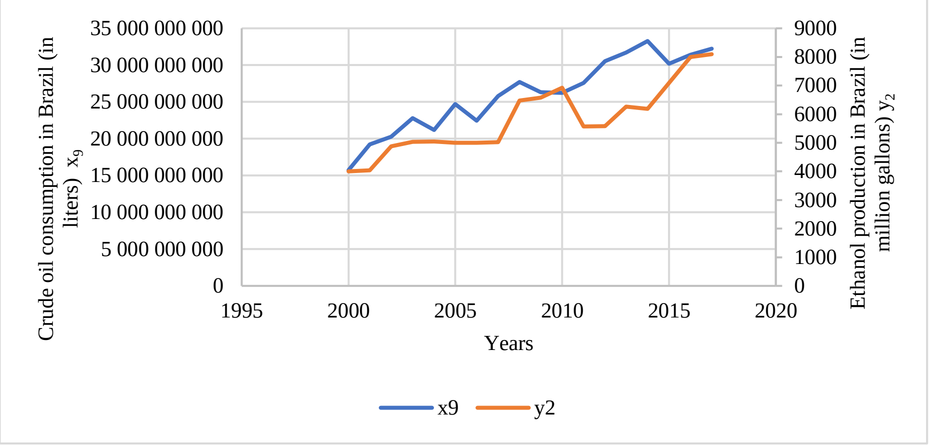
Graph 23 Dependence between Ethanol production & Crude oil consumption in Brazil.



Source: Author's elaboration based on retrieved data from UNICA, 2017.

During the time period it is showed in graph 24, how the lines are growing together over time, 2010 was a turning point and each one goes in another direction, yet in 2015 both variables had started to have the same increasing tendency again.

Graph 24 Ethanol production & Crude oil consumption trends in 2000 - 2017.

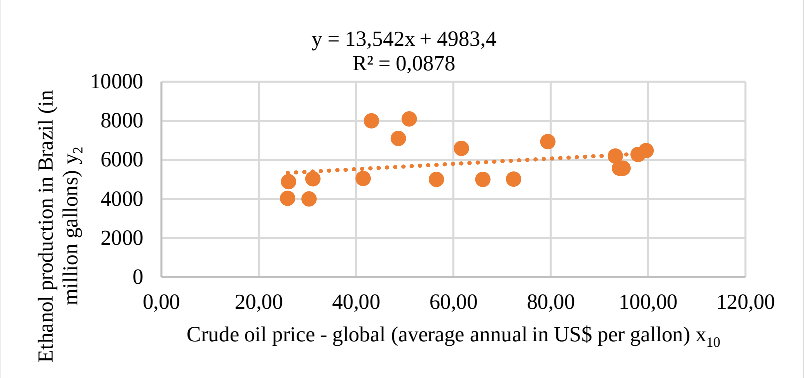


Source: Author's elaboration based on retrieved data from UNICA, 2017.

Description of graph 25 and 26

Graph 25, estimates the dependency between endogenous variable from the second equation (y_2) Ethanol production in Brazil and exogenous variable (x_{10}), Crude oil price – global. In this graph, it is displayed dependence a little a bit lower than in graph 21, means that any increase or decrease in explanatory variable (x_{10}) have only 8.78% dependence affecting the explained variable (y_2).

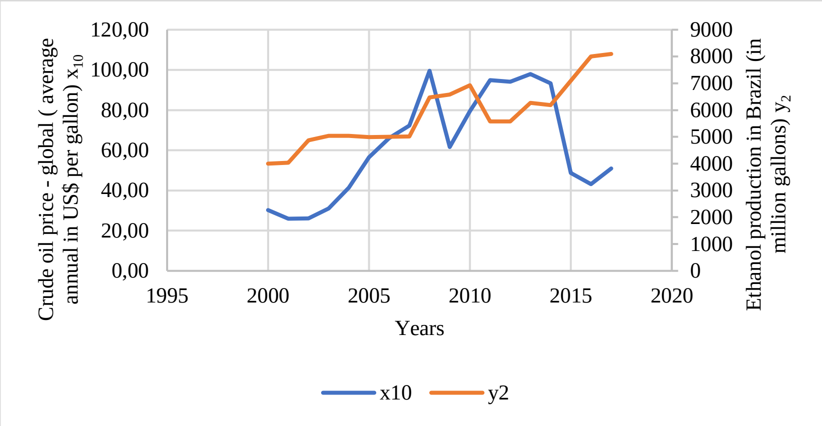
Graph 25 Dependence between Ethanol production in Brazil & Crude oil price - global.



Source: Author's elaboration based on retrieved data from UNICA, 2017 and InflationData.com, 2017.

As it is in graph 25, with very small dependency between oil price and ethanol production, it is seen in the graph below that the lines are not correlated as well. In some short time period there are same tendencies, but otherwise there are only opposite tendencies.

Graph 26 Ethanol production & Crude oil price trends in 2000 – 2017.



Source: Author's elaboration based on retrieved data from UNICA, 2017 and InflationData.com, 2017.

Correlation matrix and estimating multicollinearity

The correlation matrix is a square matrix including value 1 on its diagonal. The correlation matrix contains the pair correlation coefficients of each explanatory variable that provide information on the occurrence of the so-called multicollinearity (i.e., dependence) between two or more explanatory variables in the equation.

Values other than unit values are in the interval <-1;1>, where high multicollinearity have coefficient higher than 0.8 in the absolute value, sometimes the value is 0.9. In our model, all correlation coefficients are lower than the permissible limit 0.9, which is mentioned in the literature. High multicollinearity is an unsuitable for the model but, if it is located there it is possible to reduce multicollinearity by using dummy variable, or cut out the variable which causes the multicollinearity (Tvrdon J., 2001).

1st correlation matrix for the 1st equation, reveals the dependency between explanatory variables x_2, x_3, x_4, x_5, x_6 .

Table 9 Correlation matrix for the 1st equation.

y_{1t}	x_{2t}	x_{3t}	x_{4t}	x_{5t}	x_{6t}	
1	0.801	0.853	0.831	0.566	0.843	y_{1t}
	1	0.828	0.604	0.855	0.849	x_{2t}
		1	0.639	0.819	0.891	x_{3t}
			1	0.362	0.657	x_{4t}
				1	0.396	x_{5t}
					1	x_{6t}

Source: Author's elaboration based on data retrieved from Gretl, 2018.

2nd correlation matrix for the 2nd equation, reveals the dependency between explanatory variables y_1, x_8, x_9, x^{10} .

Table 10 Correlation matrix for the 2nd equation.

y_{2t}	y_{1t}	x_{8t}	x_{9t}	x_{10t}	
1	0.439	0.254	0.783	0.227	y_{2t}
	1	0.857	0.783	0.831	y_{1t}
		1	0.608	0.851	x_{8t}
			1	0.636	x_{9t}
				1	x_{10t}

Source: Author's elaboration based on data retrieved from Gretl, 2018.

According to table 9 and table 10, both correlation matrices for first equation and for second equation, does not show high multicollinearity between the explanatory variables. No gradual differences are needed then.

4.4.2 Parameters Estimation and Statistical Verification

All parameters with stars are statisticaly significant (S).

- *** =0.1 significance level (5% - 10%)
- ** =0.05 significance level (1% - 5%)
- * =0.025 significance level (>1%)

Parameters Estimation for 1st equation using Gretl

Picture 2 OLS - Ordinary Least Squares Method 1st equation.

```
Model 1: OLS, using observations 2000-2017 (T = 18)
Dependent variable: y1_Sugarcane_price

                       coefficient   std. error   t-ratio   p-value
  -----------------------------------------------------------------
  const                -23.0112      14.0927      -1.633    0.1308
  x2_Sugarcane_exp~      6.77723      3.54391      1.912    0.0822  *
  x3_Sugarcane_ha_~    112.444       44.8354       2.508    0.0291  **
  x4_oil_price           0.104452     0.0418796    2.494    0.0298  **
  x5_Ethanol_price       0.198105     0.682790     0.2901   0.7771
  x6_Sugarcane_pro~     -0.922607     0.438461    -2.104    0.0592  *
  x7_Time_vector        -1.75918      1.16833     -1.506    0.1603

Mean dependent var   18.94444   S.D. dependent var   7.588476
Sum squared resid    82.15030   S.E. of regression   2.732802
R-squared            0.916083   Adjusted R-squared   0.870310
F(6, 11)             20.01359   P-value(F)           0.000025
Log-likelihood      -39.20450   Akaike criterion     92.40900
Schwarz criterion    98.64161   Hannan-Quinn         93.26840
rho                  0.077788   Durbin-Watson        1.825583

Excluding the constant, p-value was highest for variable 5 (x5_Ethanol_price)

LM test for autocorrelation up to order 1 -
  Null hypothesis: no autocorrelation
  Test statistic: LMF = 0.0841219
  with p-value = P(F(1, 10) > 0.0841219) = 0.777712

White's test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 15.3455
  with p-value = P(Chi-square(12) > 15.3455) = 0.223081

Test for normality of residual -
  Null hypothesis: error is normally distributed
  Test statistic: Chi-square(2) = 0.346137
  with p-value = 0.84108
```

Source: Output retrieved from Gretl, 2018.

Parameters Verification - 1st OLS model

In the context of economic verification, it is assessed the direction and intensity of the explanatory variables on the explained variable.

Table 11 Statistical verification of the first OLS model.

Variables	Coefficient	p-value	
y_1	-23.0112	0.1308	
x_2	6.77723	0.0822	*
x_3	112.444	0.0291	**
x_4	0.104452	0.0298	**
x_5	0.198105	0.7771	
x_6	-0.922607	0.0592	*
x_7	-1.75918	0.1603	

Source: Author's elaboration based on data retrieved from Gretl, 2018.

Table 12 Statistical verification of the first OLS model.

R - squared	Adjusted R^2	Durbin-Watson	p-value (F)
0.916083	0.870310	1.825583	0.777712

Source: Author's elaboration based on data retrieved from Gretl, 2018.

The observation has been calculated for 18 years (T = 18) in years 2000 to 2017. Sugarcane price in Brazil is dependent variable (y_1) for this model, and it is explained by five explanatory variables. The intercept does not seem to be statistically significant with – 23.0112.

Testing the significance of the estimated parameters - 1st OLS model

P-value is showing dependencies towards the dependent variable. According to the output retrieved from Gretl, the OLS model displays statistically significant variables: at 10% significance level – there are no independent variables obtaining this significance level; at 5% significance level – Sugarcane harvested area in Brazil (x_3) and Crude oil price (x_4); last but not least at 1% significance level, where are independent variables Sugarcane export in Brazil (x_2) and Sugarcane production in Brazil, statistically significant at the level $\alpha = 0.1$.

Model occures three exogenous variables that are not statistically significant on any significance level, which means that Ethanol price - São Paulo (x_5) as well as the constant (y_1) and Time vector (x_7) are not statistically significant at any level. Model is statistically significant based on p-value (F) 0.777712.

Verification of the Adjusted R^2 and R^2 - 1st OLS model

The adjusted R^2 based on results is 0.870310, expresing how well were choosed variables for this model. The Coefficient of Determination says, how many percent the dependent variable is explained by changes in the independent variables in the model. The Coefficient of Determination (R^2) in model for 1st equation is quite high with 0.916083, which means that model is explained by 91.60% and there is a strong relationship between the Sugarcane price in Brazil and all five independent variables.

Testing of autocorrelation of the residuals - 1st OLS model

The Durbin - Watson test is used to determine if autocorrelation occurs in the model. The values should fit in to the interval <0; 4> (Tvrdon J., 2001). For 1st model it is estimated value 1.825583, close to the mean E (d) = 2 which is located in the interval and null hypothesis (H_0) says that in the test is statistically insignificant autocorrelation. Autocorrelation, P-value of Durbin - Watson test has been estimated as 0.769962.
The value is higher than 0.05 at the $\alpha = 5\%$ level of significance, null hypothesis (H_0) is not rejected and the assumptions of the Durbin - Watson test are not violated. Therefore the model does not prove any signs of statistically significant autocorrelation of residuals.

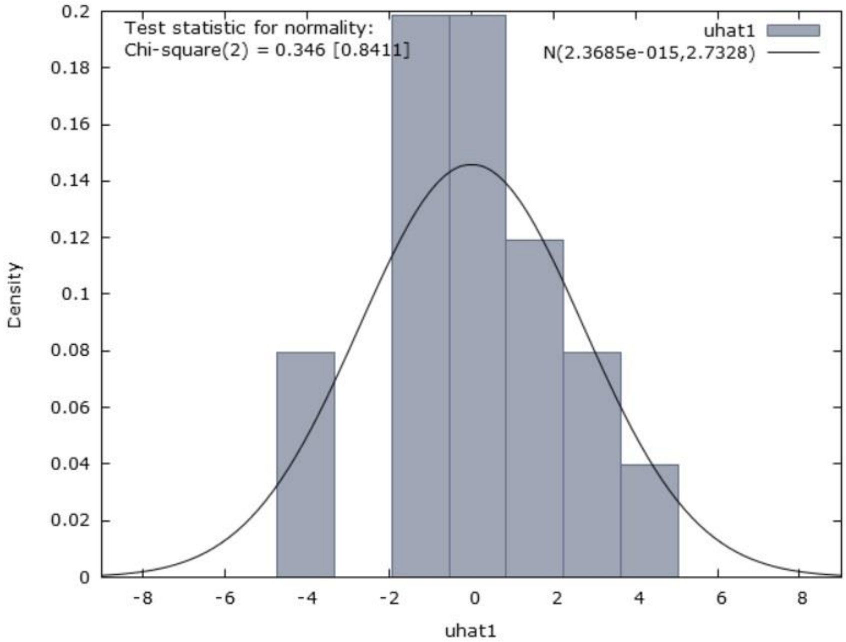
Testing of heteroscedasticity - 1st OLS model

The P - value of White's test for heteroskedasticity was estimated as p = 0.12922, thus the value is higher than 0.05 at the alpha 5% level of significance, null hypothesis (H_0) is not rejected and the assumptions of the heteroscedasticity test are not violated. Therefore the model does not prove any signs of statistically significant heteroscedasticity.

Statistic test for normality of residuals – 1st OLS model

The P - value of statistic test for normality of residuals was calculated as p = 0.902574. The value is higher than 0.05 at the $\alpha = 5\%$ level of significance, null hypothesis (H_0) is not rejected and the assumptions of the test for normality are not violated. Therefore the model does not prove any signs of statistically significant non-normality.

Graph 27 Statistic Test for Normality of Residuals - for 1st equation.



Source: Output retrieved from Gretl, 2018.

Parameters Estimation for 2nd equation using Gretl

Picture 3 OLS - Ordinary Least Squares Method 2nd equation.

```
Model 2: OLS, using observations 2000-2017 (T = 18)
Dependent variable: y2_Ethanol_production

                      coefficient      std. error    t-ratio  p-value
  --------------------------------------------------------------------
  const               5864.79         1435.88          4.084   0.0015  ***
  y1_Sugarcane_pri~   -150.439          45.7790        -3.286   0.0065  ***
  x8_Cars_ethanol        0.000706932     0.000469929   1.504   0.1584
  x9_oil_consumpti~     -1.25571e-07     8.86435e-08  -1.417   0.1820
  x10_oil_prices         8.90626         9.23771       0.9641  0.3540
  x7_Time_vector       414.768          87.1269         4.761   0.0005  ***

Mean dependent var   5820.899   S.D. dependent var   1207.631
Sum squared resid     2283191   S.E. of regression   436.1948
R-squared            0.907907   Adjusted R-squared   0.869536
F(5, 12)             23.66073   P-value(F)           7.91e-06
Log-likelihood      -131.2973   Akaike criterion     274.5946
Schwarz criterion    279.9368   Hannan-Quinn         275.3312
rho                  0.166861   Durbin-Watson        1.651822

Excluding the constant, p-value was highest for variable 5 (x10_oil_prices)

LM test for autocorrelation up to order 1 -
  Null hypothesis: no autocorrelation
  Test statistic: LMF = 0.438513
  with p-value = P(F(1, 11) > 0.438513) = 0.521473

White's test for heteroskedasticity -
  Null hypothesis: heteroskedasticity not present
  Test statistic: LM = 11.0357
  with p-value = P(Chi-square(10) > 11.0357) = 0.354747

Test for normality of residual -
  Null hypothesis: error is normally distributed
  Test statistic: Chi-square(2) = 0.545089
  with p-value = 0.76144
```

Source: Output retrieved from Gretl, 2018.

Parameters Verification - 2nd OLS model

In the context of economic verification, it is assessed the direction and intensity of the explanatory variables on the explained variable.

Table 13 Statistical verification of the second OLS model.

Variables	Coefficient	p-value	
y_2	5864.79	0.0015	***
y_1	-150.439	0.0065	***
x_8	0.000706932	0.1584	
x_9	-1.25571e-07	0.1820	
x_{10}	8.90626	0.3540	
x_7	414.768	0.0005	***

Source: Author's elaboration based on data retrieved from Gretl, 2018.

Table 14 Statistical verification of the second OLS model.

R^2 - Coefficient of determination	Adjusted R^2	Durbin-Watson	p-value (F)
0.907907	0.869536	1.651822	0.521473

Source: Author's elaboration based on data retrieved from Gretl, 2018.

All parameters with stars are statisticaly significant (S).

*** =0.1 significance level (5% - 10%)

** =0.05 significance level (1% - 5%)

* =0.025 significance level (>1%)

The number of observations is the same as it is with the first equation, it was observed for 18 years (T = 18) during the years 2000 - 2017. The dependent variable in this model is Ethanol production in Brazil (y_2) and it is explained by four explanatory variables. The constant 5864.79 is not statistically significant.

Testing the significance of the estimated parameters - 2^nd^ OLS model

P-value is showing dependencies towards the dependent variable. Based on the output retrieved from Gretl, the OLS model displays statistically significant variables at 10% significance level – constant, Sugarcane price in Brazil (y_1), Time vector (x_7); at 5% and 1% significance level - no variables with this significant level has been found in the model. Model occures three exogenous variables that are not statistically significant on any significance level, which means that Number of cars powered by biofuels in Brazil (x_8), Crude oil consumption in Brazil (x_9) and Crude oil price (x_{10}) are not significant towards the endogenous variable – Ethanol production in Brazil (y_2) according to the econometric modelling. Model is statistically significant based on p-value (F) 0.521473.

Verification of the Adjusted R^2 and R^2 - 2^{nd} OLS model

The adjusted R-squared according to results is estimated as 0.907907. The coefficient of determination expreses how well the variables were choosed for this model. The Coefficient of Determination (R^2) is higher as in previous model for 1^{st} equation with 0.870983. The estimated value means, that model is explained by 90.79% and there is a strong relationship between the Ethanol production in Brazil and independent variables.

Testing of autocorrelation of the residuals - 2nd OLS model

The Durbin - Watson test is used to determine if autocorrelation occurs in the model. The values should fit in to the interval <0; 4> (Tvrdon J., 2001). In the 2nd model it is estimated value 1.651822, the null hypothesis (H_0) says that in the test is statistically insignificant autocorrelation. The value is higher than 0.05 at the $\alpha = 5\%$ level of significance, null hypothesis (H_0) is not rejected and the assumptions of the Durbin - Watson test are not violated. Therefore the model does not prove any signs of statistically significant autocorrelation of residuals.

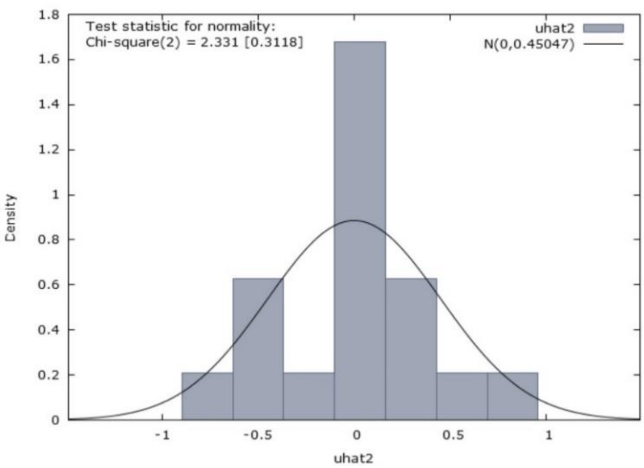
Testing of heteroscedasticity - 2nd OLS model

The P - value of White's test used for calculation of heteroscedascity, was estimated to $p = 0.354747$, thus the value is higher than 0.05 at the $\alpha = 5\%$ level of significance, null hypothesis (H_0) is not rejected and the assumptions of the heteroscedasticity test are not violated. Therefore the model does not prove any signs of statistically significant heteroscedacity.

Statistic test for normality of residuals - 2nd OLS model

The P - value of statistic test for normality of residuals was calculated as $p = 0.76144$. The value is higher than 0.05 at the $\alpha = 5\%$ level of significance, null hypothesis (H_0) is not rejected and the assumptions of the test for normality are not violated. Therefore the model does not prove any signs of statistically significant non-normality.

Graph 28 Statistic Test for Normality of Residuals - for 2nd equation.



Source: Output retrieved from Gretl, 2018.

Model including estimated parameters

$y_{1t} = -20.5862 + 7.02306 \cdot x_{2t} + 109.416 \cdot x_{3t} + 0.108073 \cdot x_{4t} + 0.198105 \cdot x_{5t} - 0.911226 \cdot x_{6t} - 1.63887 \cdot x_{7t} + u_{1t}$ (1)

$y_{2t} = 5864.79 - 150.439 \cdot \gamma_{1t} + 0.000706932 \cdot x_{8t} - 0.000000125571 \cdot x_{9t} + 8.90626 \cdot x_{10t} + 414.768 \cdot x_{7t} + u_{2t}$ (2)

4.4.3 Economic verification and elasticity of variables

Coefficient of elasticity expresses the degree of sensitivity the examined variable reaction to the changes in other variables. Lower elasticity causes that the explained variable will slowly react to a 1% change in the explanatory variables (Tvrdon J.,2001).

For the calculation of elasticity are used data from the tables right below, where the arithmetic mean is calculated from variables values and the resulting econometric model equation:

Formula for elasticity calculation

$$eii = \frac{\partial y}{\partial x} \cdot \frac{xi}{y}$$ **(53)**

Formula for elasticity calculation

1st equation

γ_{12}	7.02306
γ_{13}	109.416
γ_{14}	0.108073
γ_{15}	0.198105
γ_{16}	-0.911226

2nd equation

γ_{21}	−150.439
γ_{28}	0.000706932
γ_{29}	−0.000000125571
γ_{30}	8.90626

Calculation of arithmetic mean – 1st equation variables

y_1	x_2	x_3	x_4	x_5	x_6
18.94	***2.27***	***0.79***	***61.85***	***14.19***	***59.04***

[53] Formula retrieved from Tvrdon J.,2001.

Calculation of arithmetic mean – 2nd equation variables

y_2	y_1	x_8	x_9	x_{10}
5820.9	***18.94***	***2247851.056***	***26073788414***	***61,85***

If estimated parameters are:

> or < 1% → elastic

<-1%;1%> → non elastic

Calculation of elasticity of the parameters

1. *Elasticity of Sugarcane price and export in Brazil (e_2)*

$$7.02306 \cdot \frac{2.27}{18.94} = 0.8417\%$$

Based on the calculations, these parameters have elastic elasticity which signify that, if the Sugarcane export in Brazil will increase by 1%, the Sugarcane price in Brazil increases as well, by 0.8417%, under the ceteris paribus conditions[54]. The dependence between these two variables was 64.09% which means higher dependence, if the sugarcane export change it will have impact on sugarcane prices.

2. *Elasticity of Sugarcane price and harvested area in Brazil (e_3)*

$$109.416 \cdot \frac{0.79}{18.94} = 4.5638\%$$

Variables sugarcane price and harvested area have higher dependency (Graph 10), around 70%. Based on the calculated elasticity of the parameters, it is elastic and if the Harvested area in Brazil will increase by 1%, the Sugarcane price in Brazil increases by 4.5638%.

[54] Ceteris paribus means condition that, during estimating the effects of the estimating parameter there will not be any change in results while keeping other variables constant (BusinessDictionary.com, 2018).

3. Elasticity of Sugarcane price in Brazil and Crude oil price - global (e_4)

$$0.108073 \cdot \frac{61.85}{18.94} = 0.3529\%$$

Elastic elasticity of Sugarcane price in Brazil and Global crude oil price denote, if the Crude oil price increases by 1%, the Sugarcane price in Brazil increase by 0.3529%, under the ceteris paribus conditions. The dependence between these two variables is 69.08% and if the crude oil price will change, it will have impact on sugarcane prices.

4. Elasticity of Sugarcane price in Brazil and Ethanol price - São Paulo (e_5)

$$0.198105 \cdot \frac{14.19}{18.94} = 0.1484\%$$

If the ethanol price will change by 1% the sugarcane price will increase by 0.1484%, under the ceteris paribus conditions. The dependency between these two variables is relatively high as well (32.06%), it means that sugarcane price will be affected by ethanol price.

5. Elasticity of Sugarcane price and production in Brazil (e_6)

$$-0.911226 \cdot \frac{59.04}{18.94} = -2.84\%$$

The elasticity of sugarcane price and sugarcane production in Brazil has been estimated as a negative value and it is elastic. While there will be change by 1% in sugarcane production, the sugarcane price will decrease by 2.84%.

6. Elasticity of Ethanol production and Sugarcane price in Brazil (e_1)

$$-150.439 \cdot \frac{18.94}{5820.9} = -0.4894\%$$

If the Sugarcane price in Brazil increases by 1%, the Ethanol production in Brazil decreases by 0.4894%, under the ceteris paribus conditions. The dependence between these two variables is 23.03%, it means that sugarcane price will not affect the ethanol production that much.

7. *Elasticity of Ethanol production and Number of cars powered by biofuels in Brazil (e_8)*

$$0.000706932 \cdot \frac{2247851.06}{5820} = 0.2729\%$$

If the Number of cars powered by biofuels in Brazil will increase by 1%, the Ethanol production in Brazil will increase by 0.2729%, under the ceteris paribus conditions. According to dependency estimated (Graph 21), it is 9.91%, the Number of cars powered by biofuels would not influence the ethanol production that much.

8. *Elasticity of Ethanol production and Crude oil consumption in Brazil (e_9)*

$$-0.000000125571 \cdot \frac{26073788414}{5820.9} = -0.5624\%$$

Based on the estimated dependency for variables Ethanol production and Crude oil consumption, the influence is high with 70.26%, while the Crude oil consumption will have high influence on the Ethanol production. If the Crude oil consumption increase by 1%, the Ethanol production in Brazil decrease by 0.5624%, under the ceteris paribus conditions.

9. *Elasticity of Ethanol production in Brazil and Crude oil price - global (e_{10})*

$$8.90626 \cdot \frac{61.85}{5820.9} = 0.0946\%$$

According to the calculations of elasticity, if the Crude oil price will increase by 1%, the Ethanol production in Brazil increases by 0.0946%, under the ceteris paribus conditions. The dependency between these two variables is 8.78% which means that crude oil prices do have really low influence on Ethanol production in Brazil.

Economic verification according to economic assumption

- If other variables are equal to zero, the Sugarcane price in Brazil is equal to -1.08%.
- Increase in Sugarcane export in Brazil, causes increase in Sugarcane price in Brazil by 0.84%. This corresponds to the assumption.
- Increase in Sugarcane harvested area in Brazil, causes decrease in Sugarcane price in Brazil by 4.563%. This does not corresponds to the assumption.
- Increase in Crude oil price – global, causes increase in Sugarcane price in Brazil by 0.352%. This corresponds to the assumption.
- Increase in Ethanol price - São Paulo, causes increase in Sugarcane price in Brazil by 0.1484%. This corresponds to the assumption.
- Increase in Sugarcane production in Brazil, causes decrease in Sugarcane price in Brazil by 2.84%. This corresponds to the assumption.
- Increase in Sugarcane price in Brazil, causes decrease in Ethanol production in Brazil by 0.49%. This corresponds to the assumption.
- Increase in Number of cars powered by biofuels in Brazil, causes increase in Ethanol production in Brazil by 0.273%. This corresponds to the assumption.
- Increase in Crude oil consumption in Brazil, causes decrease in Ethanol production in Brazil by 0.563%. This corresponds to the assumption.
- Increase in Crude oil price – global, causes increase in Ethanol production in Brazil by 0.094%. This corresponds to the assumption.

4.4.4 Application of econometric model to several simulations

In this part, the econometric model and its calculations are used for application to several simulations that have been done according to hypothesis and data from theoretical part of this thesis. For the calculation it is used elasticity of the parameters, previously calculated. All simulations contain exogenous variables with high elasticity towards the endogenous variable such as: sugarcane harvested area, sugarcane export, sugarcane price, sugarcane production, crude oil consumption, crude oil price, number of cars powered by biofuels and ethanol price.

1. In the first simulation it is analysing the *Brazilian sugarcane price and Sugarcane production in Brazil.* One of the highest increase of sugarcane production in the 18 years period was by 7.17%. By how many percent would the Brazilian sugarcane price change, if the production would increase by 7.17%, under the ceteris paribus conditions?

$$\Delta x_6 \; 1\% \ldots\ldots\ldots\ldots\ldots \Delta y_1 \; (-2,84\%)$$
$$\Delta x_6 \; 7.17\% \ldots\ldots\ldots\ldots\ldots \Delta y_1 \; ?$$
$$y_1 = 7.17 \cdot (-2.84) = -20.363\%$$

If the sugarcane production increase by 7.17% the sugarcane price will decrease by 20.363%. The average sugarcane price is US$ 18.94 per tonne. After production increase the price would be US$ 15.08 per tonne. This production growth was in the year 2008 where sugarcane production was 64 million tonnes. To estimate the changes in sugarcane price that particular year it is needed to calculate elasticity for this year. And the results go as follow:

$$y_1 = 7.17 \cdot (-0.91123) = -6.53349\%$$

If the sugarcane production will increase by 7.17% in the year 2008 the price would decrease by 6.53349%. According to data sugarcane price for this year was US$ 17 per tonne and after production decrese the price would be US$ 15.88 per tonne. This corresponds to the economic assumption.

2. In the second simulation it is analysing the *Brazilian sugarcane price and export*. Based on data retrieved from FAOSTAT, the biggest sugarcane export was 31.6 million tonnes. How much would be the Brazilian average sugarcane price (US$ 18.94 per tonne) affected, if the export would increase by 20.45% (this growth was established in the year 2015), under the ceteris paribus conditions?

$$\Delta x_2 \; 1\% \ldots\ldots\ldots\ldots \Delta y_1 \; (0.8417\%)$$

$$\Delta x_2 \; 20.45\% \ldots\ldots\ldots\ldots \Delta y_1 \; ?$$

$$y_1 = 20.45 \cdot 0.8417 = 17.21\%$$

If the export will increase by 20.45% it would increase sugarcane price by 17.21%. The average sugarcane price will change to US$ 22.19 per tonne. This corresponds to the economic assumption.

3. Third simulation is focusing on *Ethanol production and Crude oil consumption in Brazil.* If the crude oil consumption will increase by 7.48%, under the ceteris paribus conditions, how would the ethanol production change?

$$\Delta x_9 \; 1\% \ldots\ldots\ldots\ldots \Delta y_2 \; (-0.5624\%)$$

$$\Delta x_9 \; 7.48\% \ldots\ldots\ldots\ldots \Delta y_2 \; ?$$

$$y_2 = 7.48 \cdot (-0.5624) = -4.2067\%$$

If the crude oil consumption would increase by 7.48% the ethanol production would decrease by 4.2067%. The average Ethanol production (5820 million gallons) would change to 5575 million gallons. This corresponds to the economic assumption.

4. The fourth simulation is calculating changes, if the *Sugarcane price in Brazil* increases by 10.5%, under the ceteris paribus conditions as it was in 2015, how would the *Ethanol production in Brazil* be affected? Average ethanol production is 5820.89 million gallons.

$$\Delta y_1 \; 1\% \ldots\ldots\ldots\ldots \Delta y_2 \; (-0.4894\%)$$

$$\Delta y_1 \; 10.5\% \ldots\ldots\ldots\ldots \Delta y_2 \; ?$$

$$y_2 = 10.5 \cdot (-0.4894) = -5.14\%$$

If the sugarcane price will change by 10.5% the ethanol production will decreased by 5.14% 5520.85 million gallons. This corresponds to the economic assumption.

5. Fifth simulation is focused on *Sugarcane price in Brazil and Crude oil price worldwide.* The highest growth of an oil price was by 37.5% was in 2008. If the crude oil price increases again by 37.5%, under the ceteris paribus conditions, how much would sugarcane prices change?

Δx_4 1%............................. Δy_1 (0.3529%)

Δx_4 37.5%..........................Δy_1 ?

$y_1 = 37.5 \cdot 0.3529 = 13.23\%$

If the Crude oil price would increase by 37.5% the average sugarcane price will be US$ 19.24 per tonne from previous value US$ 17 per tonne. These changes were probably because of the 2008 oil crisis. The highest oil price was in 2008 with US$ 99.77 per gallon. Crude oil is non-renewable source, if the prices would be increasing due to higher demand and decreasing supply, the demand for ethanol produced in our case from sugarcane will be enhancing. The sugarcane price will be affected by 13.23% if the oil prices increase by same percentage as in 2008. Due to ethanol as a substitute on the internal and external market, this rising prices were expected. This corresponds to the economic assumption.

6. The sixth simulation is calculating changes, if the *Sugarcane harvested area in Brazil* increases by 4.12%, as it was increased in 2012, how will change the average sugarcane price, if the sugarcane harvested area will change by the same percentage, under the ceteris paribus conditions? Average Sugarcane price is US$ 18.94 per tonne.

Δx_2 1%............................. Δy_1 (4.5638%)

Δx_2 4.12%..........................Δy_1 ?

$y_1 = 4.12 \cdot 4.5638 = 18\%$

Average sugarcane price would change by 18% to US$ 22.34 per tonne. Due to economic assumption - higher harvested area would make lower price because of higher supply (other influences not included such as demand, import, climatic conditions). In the year 2012 – 2013 was estimated decline with sugarcane price in Brazil by 6.25% while harvested area has been increased. This does not corresponds to the economic assumption.

7. The seventh simulation is calculating changes, how will affect *Ethanol price the Sugarcane price in Brazil*. The elasticity is not as high as expected, however for the purpose of this diploma thesis it is important to show, if the ethanol price would influence the sugarcane price somehow. If the ethanol price will increase by 34.9%, under the ceteris paribus conditions, will the sugarcane price react by an increase? Average Sugarcane price is US$ 18.94 per tonne.

Δx_5 1%.............................. Δy_1 (0.1484%)

Δx_5 4.12%...........................Δy_1 ?

$$y_1 = 4.12 \cdot 0.1484 = 5.17\%$$

Average sugarcane price would change by 5.17% to US$ 19.91 per tonne. This corresponds to the economic assumption.

5 Evaluation of results and discussion

This chapter is dedicated to summarize the results both from theoretical and practical part. The aim of this thesis is to evaluate the price correlation between sugar and biofuel in Brazil. Brazil has been major ethanol (produced from sugarcane) exporter, producer and consumer over a given period time. Brazilian ethanol is mostly produced from sugarcane therefore sugarcane has been chosen as one of the endogenous variables specifically the sugarcane price. Brazilian sugarcane has also dominant role in the international market.

For the evaluation it was used the econometric modelling with two equation model. Data were estimated in the time period 2000 – 2017. First model is calculated for endogenous variable (y_1) Sugarcane price in Brazil, using the Ordinary Least Square model (OLS) etsimating in linear regression model. There are five exogenous variable that were choosed according to economic assumption and might have an impact on Sugarcane price. First of all, it was calculated the coefficient of determination (R^2), using an equation for this purpose, which signify from how many percent the dependent variable is explained, by independent variables changes in the econometric model. The data indicate, the highest dependence on the Sugarcane price in Brazil will have Sugarcane harvested area in Brazil by 72.76% and if the harvested area will change it will have really high influence on sugarcane price. The second highest influence was estimated in the Sugarcane production in Brazil, if production has change it will affect the sugarcane price by 71.06%. The third highest above 60% is Crude oil price - global. If there will be change in crude oil price it will affect the sugarcane price by 69.08%. The dependence between the sugarcane and ethanol price was calculated as 32.06%. If the ethanol price will change it will affected the sugarcane price from 32.06% This percentage dependence is the lowest from the 1st equation. The dependencies from the second equation are relatively low against the first equation. According to same OLS model it examine the effects on endogenous variable Ethanol production in Brazil over a given period of time. The one and only highest dependence, above the 60%, is the crude oil consumption, if it change it will affect the Ethanol production in Brazil by 65.03%. The other changes will affect the Ethanol production with really small percentage. Cars powered by biofuels in Brazil by 9.9%; Sugarcane price in Brazil by 23.02%; Crude oil price – global only by 8.78%.

The adjusted R^2 for the 1st model is calculated as 0.870310, shows how well were choosed the variables for this modelling and model is explained by 91.6% by exogenous variables.

The economic assumtions were set for both, the first and the second model. Economic verification is estimating whether the economic assumption correspond to the primary assumption, which is calculated by the elasticity of average values for the given period of time. Only one assumption does not correspond to the primary assumption and that is Sugarcane harvested area in Brazil. Economic assumption was, that increase of Sugarcane harvested area in Brazil causes decrease in Sugarcane price in Brazil, however the elasticity of these variables was calculated as increase in Sugarcane price by 4.563%. If the average price in Brazil would increase by 4.12% (as it was estimated increase of harvested area in 2012) the average price would increase as well to US$ 22.34 per tonne. While the sugarcane price is increasing the ethanol production decrease, it might be because there hasn´t been satisfactory harvest of sugarcane to produce sugar as a food and smaller part of the sugarcane production goes to ethanol production where the ethanol price increase and causes the sugarcane increase as well. Ethanol is the substitute to crude oil in the international market. Increase in Crude oil consumption in Brazil, causes decrease in Ethanol production in Brazil, based on the calcullation if the Crude oil consumption increase by 1% the Ethanol consumption will decrease by 0.563%. If the crude oil consumption increase by 7.48% (as it was in the year 2007) the average ethanol production would decrease by 4.2067% to 5575 million gallons. More ethanol will be used, the more oil price will be affected by price of sugar. Since 2008 the crude oil consumtion has been declined, while the ethanol production started to increase. After this year, also the price of comodities started to increasing. However in the situation of enhancing the crude oil price, it will increase the ethanol production to meet the demand for biofuel. Ethanol production is more profitable with higher oil prices. This increase also causes the growth of the Sugarcane price. The adjusted R^2 for the 2^{nd} model is calculated as 0.907907, shows how well the variables were chosed for this modelling and model is explained by 90.79% by exogenous variables which is little less then for the first equation.

6 Conclusion

Sugarcane as it is described in the theoretical part, is used not only for feeding purposes but also for the production of ethanol. Sugarcane is cultivated on 9.5 million hectares of the land in Brazil, however it is aslo produced in Latin America and Asia. Around 45% of brazilian sugarcane is used to producing the sugar and the remaining 55% is for ethanol production, where 90% is used for fuel in the form of bioethanol (biofuel). Biofuel is a substitute for largely used crude oil in the international market. While the crude oil is non-renewable source, the experts are concerned about its production to the future, biofuels have gained a high interest not only by experts but also by the general public. The history of biofuels dates back to the beginning of the 20th century, where attempts have already been made to find a way how to powered cars biofuels – it managed to use wood combustion (wood gas) at the back of the car, that was able to powered the car. Those attemps were also in Brazil (São Paulo) where they tried to use alcohol since the sugarcane ethanol is an alcohol-based fuel.

Sugarcane has been one of the most important crop that has been cultivated in Brazil for decades. Brazil produce around 25% of global sugar and ethanol production. As the largest exporter and producer of sugarcane and ethanol (processed from sugarcane), the domestic ethanol consumption reaches up to 90%. According to research papers, increasing demand for alternative fuel (bioethanol) with highest production in Brazil, is influenced by increasing oil prices, that might cause sugar price increase. Therefore the more ethanol will be used, the more the price of oil will be affected by the price of sugar. Based on the diploma thesis econometric model calculation, for 2 endogenous variables (y_1, y_2), the increasing crude oil price will affect the sugarcane price in Brazil by 0.3529%, if the oil price will increase by 1%, under ceteris paribus condition. However, this growth do not influence the Ethanol production in Brazil, if so, it will be only by 0.0946%, where the dependency between these examined variables is 8.78% which is not that high either. The aim of the diploma thesis is to find out, what is the relationship between the price of sugar and biofuels. According to the calculations it has been estimate, if the ethanol price - São Paulo increase by 1% the sugarcane price will increase by 0.1484%. The dependency between variables is relatively high with 32.06%. Sugarcane price is more affected by the Sugarcane export in Brazil, the Crude oil price – global and the Sugarcane production in Brazil. Sugarcane harvested area with high elasticity affect the sugarcane price by 4.5%, however it does not correspond with the economic assumption which says, if the sugarcane harvested area increase, sugarcane price decrease. Ethanol production in Brazil is higly influenced by crude oil consumption, if the consumption increase by 1%, the ethanol production will decrease by 0.56%, which correspond with previous assumption. Crude oil consumption also has the hight influence on Ethanol production by more than 70%. Ethanol price is affected by Sugarcane price as well as with high elasticity, if sugarcane price will increase by 1%, the Ethanol production in Brazil decrease by 0.4894%. Other variables (Crude oil price – global, Number of cars powered by biofuels in Brazil) do not have influence on the ethanol production as the previous ones but all of them are correspond to the economic assumption.

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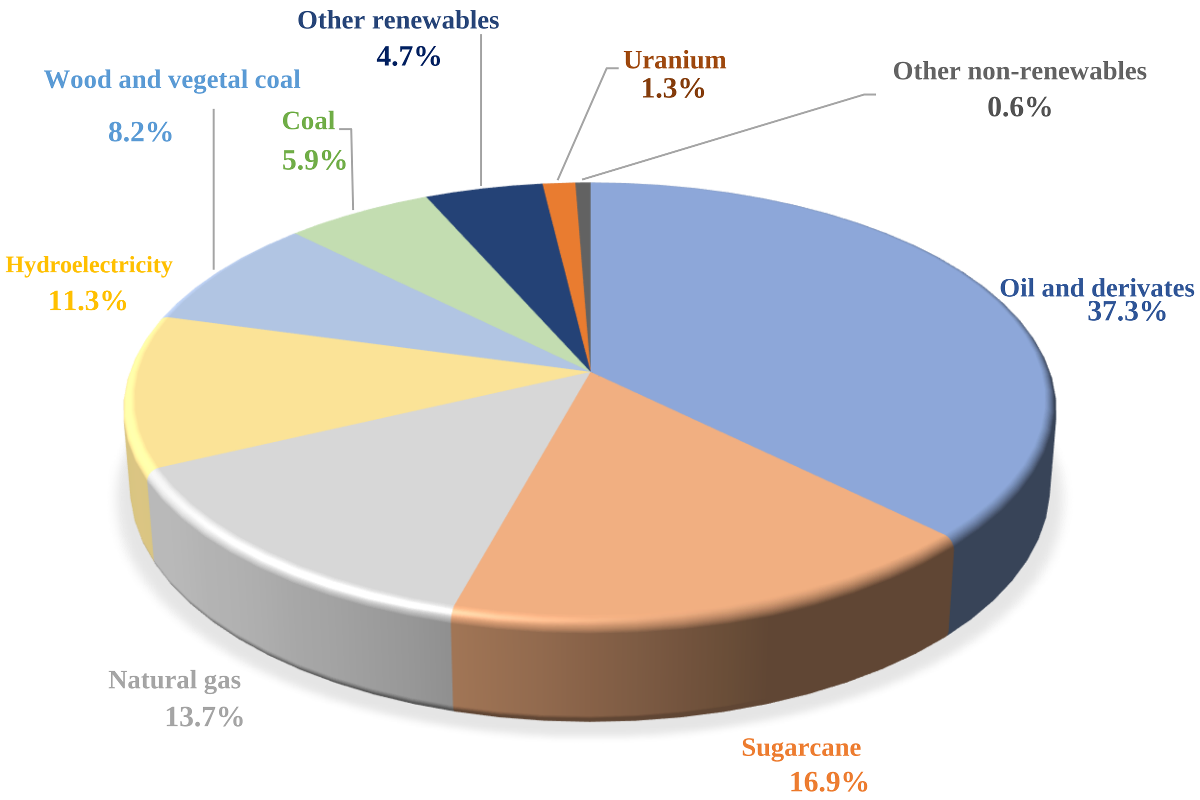
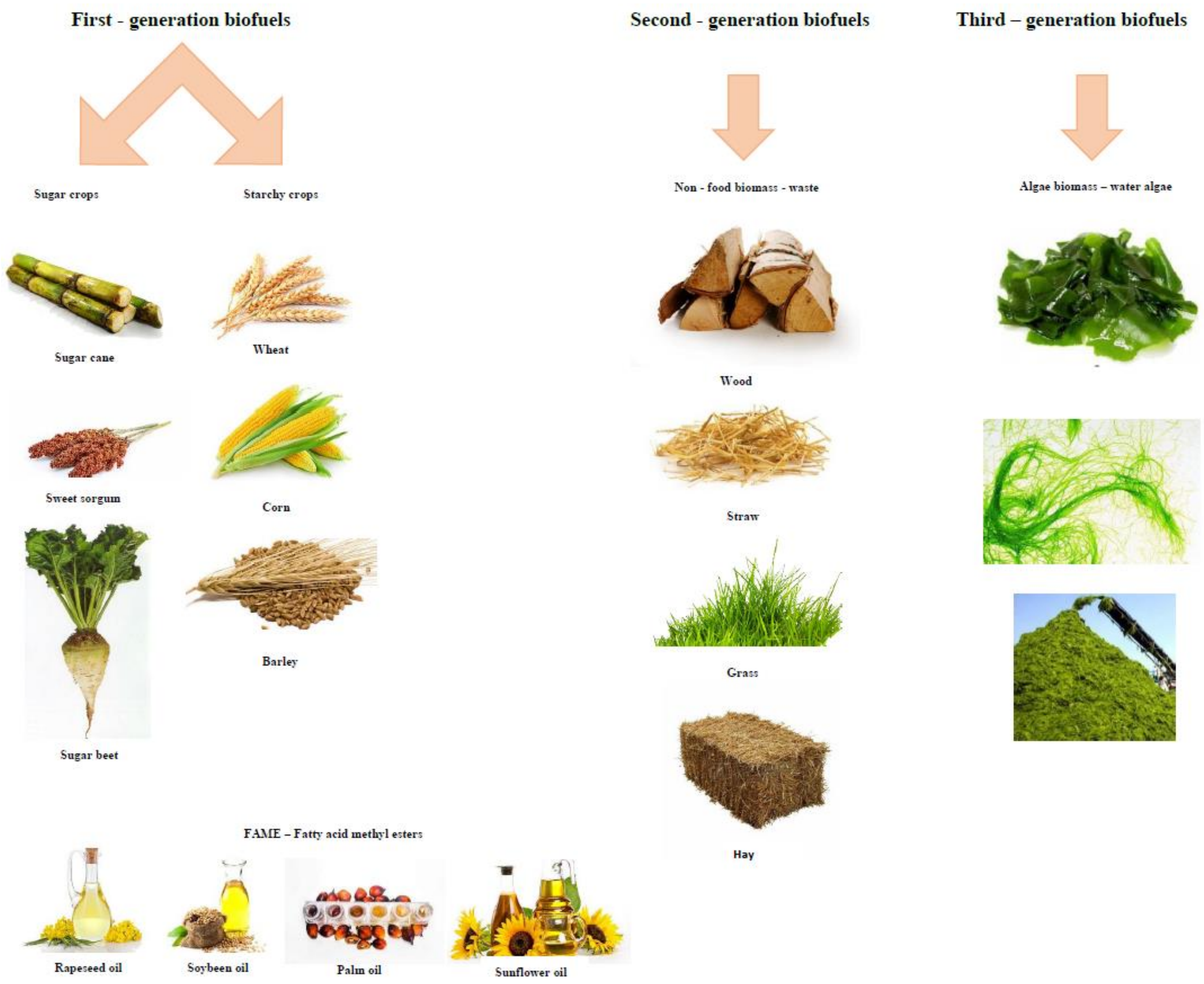
8 Appendix

Appendix 1: Cars powered by wood gas in 1944.

Appendix 2: Brazilian Energy Matrix in 2015. Author's elaboration based on data retrieved from UNICA, 2017.



Appendix 3: The Distribution of Biofuels and the Use of Biomass. Author's elaboration based on information from chapter 3.3.6.



Appendix 4: Brazil - General information. Data retrieved from The World Factbook, 2017.

Population: 207,353,391 (2017 est.)
Density: 24.35/km^2
Population growth rate: 0.73% (2017 est.)
Birth rate: 14.1 births/1,000 population (2017 est.)
Death rate: 6.7 deaths/1,000 population (2017 est.)
Net migration rate: -0.1 migrant(s)/1,000 population (2017 est.)
Infant mortality rate: total: 17.5 deaths/1,000 live births
Religion: 64.6% Catholic, 22.2% Protestant, 8.0% Irreligion, 2.0% Spiritism, 3.2% Others
Official and national language: Portuguese
Capital city: Brasília
Largest city: São Paulo
Location: Eastern South America, bordering the Atlantic Ocean
Total area: 8,511,965 km^2
Land area: 8,456,510 km^2
Land boundaries: total 14,691 km
Climate: mostly tropical, but temperate in south
Terrain: mostly flat to rolling lowlands in north; some plains, hills, mountains, and narrow coastal belt
Land use: agricultural land: 32.9%, arable land 8.6%; permanent crops 0.8%; permanent pasture 23.5% forest: 61.9%, other: 5.2% (2011 est.)
Natural hazards: recurring droughts in northeast; floods and occasional frost in south
Environmental current issues: deforestation in Amazon Basin destroys the habitat and endangers a multitude of plant and animal species indigenous to the area; there is a lucrative illegal wildlife trade; air and water pollution in Rio de Janeiro, Sao Paulo, and several other large cities; land degradation and water pollution caused by improper mining activities; wetland degradation; severe oil spills.
Urbanization: urban population: 86.2% of total population (2017), rate of urbanization: 0.99% annual rate of change (2015-20 est.)
Major urban areas - population: Sao Paulo 21.066 million; Rio de Janeiro 12.902 million; Belo Horizonte 5.716 million; BRASILIA (capital) 4.155 million; Fortaleza 3.88 million; Recife 3.739 million (2015)
Obesity - adult prevalence rate: 22.1% (2016)
GDP (PPP): Total - $3.141 trillion (8th), Per capita - $15,200 (2016)
Agriculture - products: coffee, soybeans, wheat, rice, corn, sugarcane, cocoa, citrus; beef
Industries: textiles, shoes, chemicals, cement, lumber, iron ore, tin, steel, aircraft, motor vehicles and parts, other machinery and equipment
Industrial production growth rate: -3.8% (2016 est.)
Labour force - by occupation: agriculture: 10%**;** industry: 39,8%**;** services: 50,2% (2016 est.)
Unemployment rate: 11,3% (2016 est.), country comparison to the world: 150
Budget surplus (+) or deficit (-): -1% of GDP (2016 est.), country comparison to the world: 67
Public debt: 69,9% of GDP (2015 est.), country comparison to the world: 51
Exports: $184,5 billion (2016 est.), country comparison to the world: 26
Exports - commodities: transport equipment, iron ore, soybeans, footwear, coffee, automobiles
Exports - partners: China 19%, US 12.6%, Argentina 7.3%, Netherlands 5.6% (2016)
Imports: $139,4 billion (2016 est.), country comparison to the world: 30
Imports - commodities: machinery, electrical and transport equipment, chemical products, oil, automotive parts, electronics
Imports - partners: US 17.6%, China 16.9%, Argentina 6.7%, Germany 6.6%, South Korea 4.4% (2016)