Czech University of Life Sciences Prague

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Diploma Thesis

Cost Benefit Analysis of Selected Biofuels in the Czech Republic

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Declaration

I declare that I have worked on my diploma thesis titled "Cost Benefit Analysis of Selected Biofuels in the Czech Republic" 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 their person.

In Prague on 30.03.2016 ______________________________

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Analýza Nákladů a Přínosů Biopaliv v České republice

Souhrn

V posledních letech se biopaliva stala jedním z hlavních paliv v energetickém sektoru. Česká republika rovněž rozvinula sektor s bio palivy, a sestavila obecný konsenzus o jejich důležitosti a výhodách. Nicméně řada vědců a asociací, jako Sorda a kol., Ajanovič, Organizace spojených národů pro výživu a zemědělství a další, vidí v této expanzi bio paliv několik nedostatků. Z tohoto důvodu čisté náklady spojené s využitím bio paliv nejsou v České republice jasně stanoveny. Je zde mezera ve vyhodnocení nákladů a přínosů tohoto průmyslu. Cílem této diplomové práce je zmírnit tuto mezeru výzkumem dopadů ekonomického blahobytu spojeného s užitím bionafty a bioethanolu, v rozvíjejícím se průmyslu České republiky se zahrnutím politiky bio paliv. Analýza nákladů a přínosů byla provedena na základě teorie o spotřebitelském a producentském přebytku. Tato analýza je podpořena ekonometricky modelovanými funkcemi poptávky a nabídky vybraných bio paliv. Výsledky tohoto výzkumu jsou protichůdné, nicméně je jisté, že využití bionafty a bioethanolu a dotací s nimi spojenými, se do ekonomiky státu projevilo se ztrátou 9 109 mil. Kč. Výsledky výzkumu poukazují na problém s příliš intenzivní finanční podporou ze strany vlády České republiky v sektoru biopaliv, a zároveň upozorňují na potřebu nárůstu nepřímých metod financování, jako jsou investice do R&D a do infrastruktury.

Klíčová slova: Biopaliva, bionafta, ethanol, dotace, Česká republika, obnovitelná energie, analýza nákladů a přínosů, regresní analýza, ceny potravin, náklady na životní prostředí, ekonomické náklady, efekt dobrých životních podmínek, spotřebitelský přebytek, přebytek výrobce.

Cost Benefit Analysis of Selected Biofuels in the Czech Republic

Summary

In the last several years biofuels became one of the main drivers of the energy sector. Czech Republic as well developed its biofuels sector and general consensus on the importance of advantages related to biofuels has been established. However, many researchers and associations such as Sorda et al., Ajanovic, Food and Agriculture Organization of the United Nations, etc. see several shortcomings of biofuels industry expansion. Therefore, the net costs of biofuels utilization in the Czech Republic are not clear yet. There is a gap in the estimation of economic costs and benefits of the industry. This thesis aims to narrow the gap with a research on economic welfare effects of the biodiesel and bioethanol industry expansion in the Czech Republic including the factor of biofuels policies. Cost benefit analysis was conducted with a consumer and producer surplus theory approach based on econometrically modeled functions of selected biofuels demand and supply. The results of the research are contradictory, however it is clear that biodiesel and bioethanol utilizations and subsidies presence on the market result in the net economic loss of 9.109 million CZK. The research outcomes prove the problem of too intense direct financial support of the biofuels sector in the Czech Republic and the need to increase indirect methods of support such as investments in R&D and infrastructure development.

Keywords: Biofuels, biodiesel, bioethanol, subsidies, Czech Republic, renewable energy policy, cost benefit analysis, regression analysis, food prices, environmental costs, economic costs, welfare effect, consumer surplus, producer surplus.

Extended Abstract

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1 Introduction.

In 20th century life was driven by fossil energy and even nowadays fossil fuels cover the most part of world's energy demand. However, in recent years, renewable energy has become a topic of a high scientific and practical interest. Renewable energy sources counts for 13% of total global energy consumption (Ho, Ngo, Guo, 2015) and include biomass, wind, geothermal sources, sun, etc. Bioenergy production is one of the most developed alternatives to fossil energy.

Several main factors provided attention to renewable energy sources: high dependence on limited fossil fuels and unstable oil market, climate change problems (M. Burkart, S. Mayfield, 2013). Firstly, there is a clear tendency for more and more countries to give high priority to the energy security and independence. Instability in Middle East countries influences negatively to oil market and world economy. Miller (2014) has reviewed the literature and mentions that sufficient amount of the previous studies have reported rapid oil supply ran out in the nearest future. He as well claims that: "Simple mathematics says that if the rate of consumption exceeds the rate of resupply, eventually the supply will be used up." Therefore, several researchers believe that biofuels industry development can be a chance for developed and developing countries to supply their energy demand within the country and diversify export structure.

Climate change is another significant problem that forces countries to change their energy strategies. According to Statista (2015): "Over the past decade, carbon dioxide emissions increased by around nine billion metric tons". Asia Pacific region is a leader in carbon dioxides emissions followed by North America, EU and Eurasia (Statista, 2015).

Kyoto Protocol was created in 1997 and approved in 2005 in order to decrease the problem of GHG (Green House Gas) emissions (Kyotoprotocol.com, 2015). This Protocol set targets to decline GHG emissions for its members: on average it is 5% reduction over 1990 levels and for EU the target varies from 6% to 8% (Capros, 2000).

In order to face Kyoto Protocol obligations and increase energy independence countries have overall two ways: to develop alternative energy industries or decline demand for fossil fuel within the country by decreasing number of transport. Now it is impossible to remove completely all transport system, which, according to Leite et al. (2013), "plays a major role in production of GHG emissions as well as being responsible for 28% of total world primary energy consumption, mainly consisting of fossil fuels". As far as the transport system is still one of the essential part of the life, countries were forced to invest in biofuels (green fuels) production.

The term biofuel refers to “liquid or gaseous fuels for the transport sector that are predominantly produced from biomass” (Demirbas, 2008). Biofuels are produced from biological waste and biological raw materials such as corn, sugar cane, raps and soybean. Most frequently analyzed biofuels are bioethanol and biodiesel. As already mentioned, green fuels have several advantages, which may be the key to successful replacement of fossil fuels.

However, an increasing concern on biofuels sustainability forces researches to pay more attention to the analysis of potentially negative environmental consequences, question of food vs. fuel competition for agricultural land and economic unsustainability of some kind of biofuels due to high prices and lack of technology (van Eijck et al., 2014, p 115-116).

Despite disadvantages, development of biofuels may become an important step to strengthening the ecological energy strategies around the world. However, production and utilization of green fuels requires governmental control and development of effective policies that may help to decrease unsustainable effects.

Biofuels governmental policies vary from country to country and from region to region depending on economic, social, environmental situation and supply of biomass resources (Banse et al., 2011). North, South America and EU are the leading producers of biofuels in the world, thus significant number of studies were based on the policies of these regions.

European Union, however, have a specific structure that influences the character and forms of the policies in alternative energies as a whole and biofuels in particular. Each state of EU has its own economy and industry structure that are influenced by existing interconnection within the European market. European energy policy is closely connected to Kyoto Protocol’s targets and obligations. Rabonil et al. (2014) lists several official directives and documents that regulate energy sector in EU, such as The “Green Paper” (2000), The Directive 2003/30/EC (2003) or The Renewable Energy Directive (RED), etc. Implementation of EU policies may vary from member to member as each country of EU has its own energy strategies, however all members have common goals they need to fulfill.

Czech Republic is a member of European Union since 2004. As all the members, this country should follow all directives and plans of EU, yet it also has its own energy strategy.

Czech Republic has one of the highest levels of economic development among new members of EU, however, this country has significant problems with pollution. According to Numbeo data, Czech Repuplic have high pollution index of 42.49, while German is 29.2 (Numbeo, 2016). Biofuels industry was considered to have promising perspectives in Czech Republic and government settled several programs supporting this industry.

Many scientists studied the question of biomass and its usage as well as analyzed overall efficiency of EU environmental policy implementation in Czech Republic. Šauer et al. (2012) conducted a research on assessment of environmental policy implementation on case studies of air emission from large plants and solid waste landfilling in CR. Jehickova and Morris (2007) have estimated effectiveness of the Czech government policy supporting the usage of wood waste as a fuel. Lewandowski et. al (2011) modeled biomass prices for bioenergy market in Czech Republic.

Despite an existing adequate amount of studies mentioned above, there has been insufficient amount of studies for cost benefits estimation of biofuels industry specifically in the Czech Republic. To the author’s knowledge extent, there were no research papers, available in English, with the analysis of the biodiesel and bioethanol utilization contribution to the welfare of the Czech Republic. While biofuels production and consumption in CR have been growing, the full cost of biofuels utilization is not clear. It is necessary to conduct cost benefit analysis of biofuel utilization to propose adequate recommendations for the biofuels policies that would maximize social welfare in the Czech Republic.

2 Thesis Aim, Objectives and Methodology.

This chapter will present the main aim of the thesis, objectives that will help to achieve it and the methodology of the research with several research limitations.

2.1 Objectives.

Biofuels industry is rapidly developing in the frame of new energetic and environmental strategies around the world. The Czech Republic is not the exception. Czech government implemented wide programs of financing the biofuels sector expansion. Despite several researches done on the topic of biofuels in the Czech Republic, there is still a gap in the estimation of economic costs and benefits of the industry. This thesis aims to narrow the gap with a research on economic welfare effects of the biodiesel and bioethanol industry expansion in the Czech Republic including the factor of biofuels policies.

The research questions of this thesis are:

- What are the economic costs and benefits of biodiesel and bioethanol utilization in the Czech Republic;
- How these costs and benefits ratio contributes to the welfare of the country.

The aim will be fulfilled by accomplishing of these research objectives:

- Examine the concept of biofuels and their main benefits and shortcomings.
- Identify main factors of biofuels supply and demand.
- Examine the existing world practice of policies on biofuel industry including European Union.
- Study and compare the existing policy on biofuels in the Czech Republic to the overall best practice biofuel policies in EU.
- Calculate producer and consumer surplus and total welfare effect of biodiesel and bioethanol utilization in the Czech Republic.
- Propose recommendations on increasing the efficiency of biofuels policy in the Czech Republic based on results gained from cost benefit analysis.

2.2 Methodology.

According to Holland (2012), cost benefit analysis projects and policies in general helps to provide information to answer several question, depending on the time framework chosen for the analysis:

- Ex-ante scale. Is or will the activity be worthwhile? Here the decisions are taken on what project to choose, if it is a profitable to invest in the particular project (policy), etc.
- Ex-post scale. Was the project (policy) worthwhile? Here the activity is evaluated based on existing statistics and results.

Massiani (2015) divides existing approaches to the cost benefit analysis into three main groups:

1. *Forecasts* which are made by creation of simplified market models.
2. *Simulation scenarios models,* which Massiani mainly uses for his research. This group deals with comparison of different modeled scenarios of resources allocation.
3. *Evaluation of the outcomes.* This group goes along with the ex-post classification mention above. The analysis of cost and benefits is made based on the real observations of existing market or project.

The literature review shows that one of the most used approach to the cost benefit analysis is simulation scenarios, where authors try to predict and evaluate the outcomes of activities and compare two or more scenarios (Massiani, 2015; Santamaria et al., 2015; Thengane et al., 2014). There are several authors, who use ex-post analysis (Bell et al., 2011; Lu et al., 2012; Tol, 2012;) and those, who combine scenarios approach and ex-post evaluation (Gao et al., 2016; Møller et al., 2014). This thesis aims to evaluate the economic welfare effects of the biodiesel and bioethanol industry expansion in the Czech Republic, therefore the best approach is considered to be the ex-post analysis, based on real industry statistical data.

In the frame of outcomes evaluation, there are several papers and books that connect the cost benefit analysis with the consumer and producer surpluses. Dreze and Stern (1987) as well as Campbell and Brown (2012) mention the relevance of the welfare analysis (consumer and producer surplus) and cost-benefit analysis. Puget Sound Regional Council Report (2009) presents the cost benefit analysis using the surplus theory, however, they mention only consumer surplus and do not analyze the producer surplus. Miron (2009) names the cost benefit analysis is a key application of the consumer and producer surplus theory.

The author of this thesis agrees with a tight connection between the welfare estimation and cost benefit analysis as this combination allows building the wider picture of outcomes. Therefore, the methodology of this paper is built on the ex-post evaluation analysis using the theory of consumer and producer surpluses. In general, the methodological framework of this thesis looks as follows:

1. Research and building of the theoretical framework on biofuels industry in the Czech Republic.
2. Comparative analysis of the biofuel policies in different countries.
3. Building economic and econometric models (Least square methods) to estimate the production and consumption functions of the biodiesel and bioethanol in the Czech Republic.
4. Plotting the curves of supply and demand for biodiesel and bioethanol in the Czech Republic using real data of December 2014 observations.
5. Estimating the consumer and producer surpluses of biodiesel and bioethanol industry and the subsidies influence on the total welfare of the country.

In the first part of the research there were methods of secondary research used, the gathering of scientific literature and the analysis of published data connected to the development of the biofuels industry, its main definitions and characteristics. Closer attention was paid to the analysis of bioethanol and biodiesel main characteristics.

Further based on available scientific source the main benefits and shortcomings of the biofuels were analyzed. This analysis helped to build theoretical basis for the understanding of costs and benefits of biofuels utilization. Furthermore, comparative analysis of the benefits and challenges of first generation and second generation biofuels was made.

The analysis of the main factors influencing demand and supply of biofuels was made in order to provide information for the settlement of the econometric model of bioethanol and biodiesel demand and supply in the Czech Republic.

Next step was to examine the world practice of the biofuel policies to build a picture of the most used methods and instruments of support and control biofuels market. The Czech Republic biofuel policy was also examined in order to build the picture of the current situation on the market and main factors influencing biofuels from the government side. The policy was compared to the main world practices. This analysis was utilized to create recommendations after the estimation of the economic welfare effect of bioethanol and biodiesel utilization in the Czech Republic.

Subsidies effects to the consumer and producer surplus and total welfare were illustrated and explained in the theoretical framework in order to understand the mechanisms and apply them to the estimated model of biodiesel and bioethanol supply and demand curves in the Czech Republic.

In order to answer the research questions the econometric model of biodiesel production and consumption was constructed. The first step was identification of the main explanatory variables that will be included in the regressions, based on theoretical background. The main factors of supply are the price of biodiesel and bioethanol (CZK per ton), amount of subsidies in million CZK (as it is considered to be a very significant factor), rapeseed and sugar beet prices in CZK per ton (as costs of production). Main consumption factors are biodiesel and bioethanol price (CZK per ton), average salary (CZK), NAFTA and gasoline prices in CZK per ton (as substitute prices) and blending obligations of biodiesel and bioethanol in %.

The second step was the data mining, which was challenging due to the low market transparency. The data was gained on a monthly basis from January 2010 to December 2014, overall 60 observations. The main sources used for data mining were Czech Statistical Office, Czech Ministry of Industry and Trade, The Ministry of Agriculture of the Czech Republic and web-source Kurzy.cz.

The stationarity of time-series was tested with the Augmented Dickey-Fuller unit root test using Gretl Software. The test showed that almost all time-series were non-stationary; accordingly, the data had to be modified. The author has chosen the method of seasonal dummy variables, as it showed better model quality, than first-differences method and logarithms introduction (Granger and Newbold, 1974; Woolbridge, 2009).

After the data was modified, it was possible to build the basic econometric model, where the author introduced main variables-factors of production and consumption of biodiesel and bioethanol in the Czech market. Before running the regression the model was modified again due to multicollinearity between blending obligations (BlObl) variable and fossil fuels price (FFPr) variable.

Methodology literature review showed that many authors recommend to use two steps least square method while building supply and demand curves instead of simple least square method. This is explained by the existing simultaneous relationship between supply and demand functions, thus the separate estimation may lead to biased results (James and Singh, 1978; Majerus, 1982; Epple and McCallum, 2005; Lin, 2011; Liu, 2011).

When the final functions of production and consumption were built, it was necessary to run the verification tests on normality of statistical error, the presence of heteroscedasticity and autocorrelation. Parameter significance was tested by the p-value criteria.

In order to plot the supply and demand functions of biodiesel and bioethanol in the Czech Republic, the real observation data (December 2014) we put to the estimated functions of selected biofuels production and consumption. The producer and consumer surpluses we calculated using graphical and mathematical methods. The subsidy was introduced to the model via assumption based on the real observations. The cost benefit analysis was held comparing the changes in consumer and producer surpluses and the government spending connected to the subsidies on the biodiesel and bioethanol market of the Czech Republic.

2.3 Research Limitations.

The main challenge of this research is low transparence of biofuel industry in general and in the Czech Republic particularly. European Union have implemented several Directives and laws on biofuels industries in member countries, however informational support on the industry is very poor. The problem of low information availability results in limitations with data that was gained for this particular research.

Data set for the regression analysis was limited to 60 monthly periods, which is enough to build the model, however the quality of the model could be better with the extension of the data set.

3 Literature review

3.1 Biofuels Industry: Main Definitions and Characteristics.

This chapter will provide analysis on the basics of biofuel industry, presenting the main definitions and characteristics as well as critical discussion on benefits and challenges of biofuels implementation. Author presents charts and statistical evidence on the positive and negative influence of biofuel industry expansion. Furthermore, the analysis of the industry supply chain allows making conclusions on the main determinants of biofuels supply and demand. There will be made the comparative analysis of the biofuel policies in the main players of the market and the analysis of the Czech Republic biofuel policy.

3.1.1 Industry development history.

Historically bioenergy was the first type of energy available to people. They have used wood to warm their houses, to cook and later as a fuel for the transport. Plant and vegetable oils also have a long history of development.

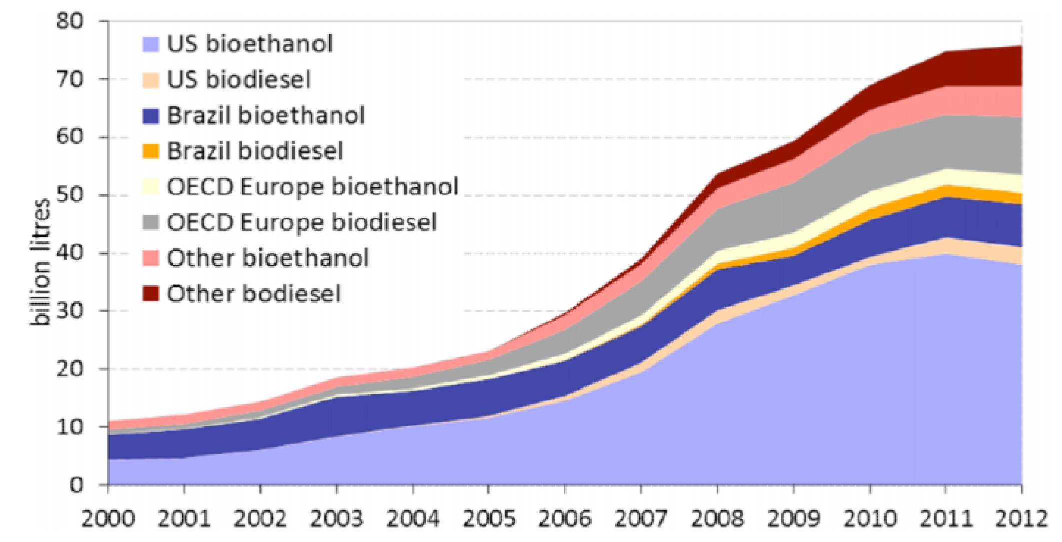
In the early 18th century vegetable fats and oils were used for street lighting and house warming. Next century was rich for the inventions as there was the first alcohol engine created by Samuel Morey in as well as Otto-cycle moving on ethanol by Nicholaus Otto (Kolb, 2014).

Bioethanol as a fuel was used long time before petroleum. However, particularly in U.S., bioethanol had no opportunity to become the leading fuel due to spirits tax imposed by the government in 1860 to finance the Civil War costs (Kolb, 2014). After the war period Henry Ford promoted bioethanol as a fuel for agricultural machinery and vegetable oils as a transport fuel were introduced by Diesel (Goldemberg, 2014).

In 1930s around 30 industrial countries (tropical countries and EU) implemented blending obligations or tax subsidies to maintain biofuels industry. Brazil with a long history of sugarcane bioethanol development and in 1930 imposed minimal obligatory blending requirements of 5% (Goldemberg, 2014).

In 1973 many countries oil-importers realized that their foreign debt increased heavily due to oil shock. It became critical to each economy to develop technologies that will allow to decrease the dependence on import of fossil fuels. After oil prices recovery governments did not pay enough attention to biofuel policies and programs maintenance, which resulted in production decline. During that period analysts were predicting the rising importance of sustainable fuel and advised to continue research and development processes not only because of economic, but also environmental reasons.

Figure 1 Global biofuel production, billion liters 2000-2012



Source: European Parliamentary Research Service, 2015.

In the 21st century biofuel industry may be seen as a part of global bioenergy industry. Figure 1 illustrates a rapid growth of biofuels production in the world, which, according to some analysts, is connected to introduction of subsidies into this sector. It can can be seen that US is still a leader in biofuels industry, however Europe shows significant increase especially in biodiesel production.

Total world production of biofuels in 2013 counted for 120 billion liters, which covered about 3.5% of international transport fuel demand (OECD/IEA, 2013). EU bioethanol production in 2014 is estimated at 5.3 billion liters (GAIN Report, 2015) According to some forecasts by 2050, bioethanol and biodiesel would be the dominant fuels to power passenger cars and heavy vehicles. (Guo et al., 2015).

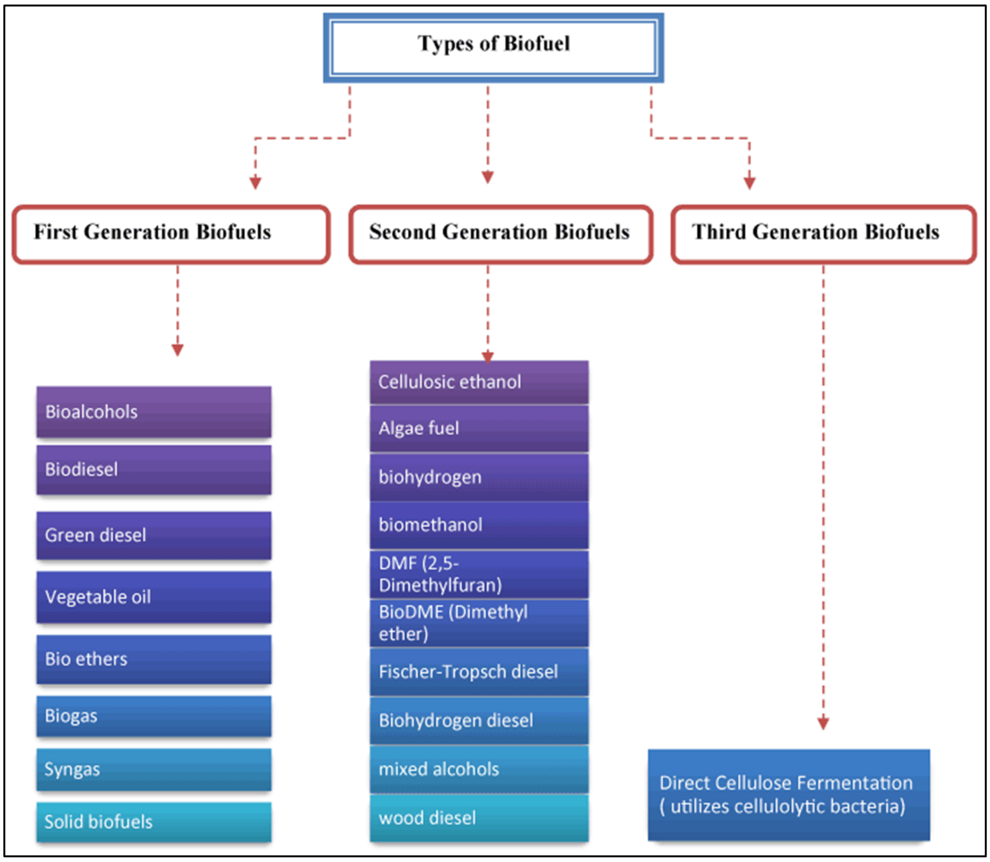
3.1.2 Biofuels definition and types.

One of the most widespread definitions of biofuels in the literature presents it as a liquid or gaseous transport fuel predominantly made of biomass and created to supplement petroleum-based fuels. (Demirbas, 2008; Boucher et al., 2014; Ho et al., 2014; Speight and Radovanovic, 2015; etc.) In biofuels industry biomass usually stands for biological material that was derived from a living organism as well as from plants. (Biomass Energy Center, 2011). Biomass is currently the only renewable feedstock material to produce liquid fuel. There are several types of biofuels, according to the kind of biomass that is used for the production, according to the technology of production or according to the form of the biofuel.

According to the technology and biomass used for the production, biofuels can be divided into three main groups: first generation biofuels, second generation and third generation (see Figure 2). Important fact is that the structure, functions and properties of biofuels do not change on the way from the first to the third generation. The evolution is in the sources that are used to produce biofuels (Sameere V. et al., 2011).

First generation biofuels (1G) are made of biomass derived from food crops. These biofuels are mainly derived from sugar, starch, animal fats and vegetable oil. The main sources for the first generation biofuels are sugarcane, wheat, corn, soybeans, rapeseed, palm oil and sugar beet. As can be seen from the Figure 2, first generation biofuels can be liquid – bioethanol, biodiesel, vegetable oils and bio ethers; gaseous biofuels – biogas and syngas; and solid biofuels. 1G biofuels are well-known and widely used as the technology of production allowed to put them to mass market (Sims et al., 2008).

Figure 2 Classification of biofuels



Source: Sameera V. et al., 2011

Second generation biofuels (2G) or "improved biofuels" are derived using new technologies from non-food sources: certain types of specially grown energy crops, waste and food waste timber. The final product (eg, cellulosic bioethanol) in their physical properties is the same as that produced by the technology of the first generation, but the product 2G is considered more acceptable in terms of sustainable development. A new trend is the use of bioenergy feedstock algae (see Figure 2). Energy output processing of algal biomass is considered to be superior to any other non-food raw materials. Other second generation biofuels are cellulosic ethanol, biohydrogen, biomethanol, mixed alcohols, wood diesel, etc.

Several commercial plants producing 2G biofuels already exist in US mostly also in China, Germany, Sweden, etc. However, overall production is still very low comparing to the 1G biofuels and to the goals that were set for advanced biofuels. For example, in the United States the Environmental Protection Agency (EPA) had to decrease mandates for 2g biofuels usage production every year since 2010. Instead of the planned 1.75 billion gallons in 2014 there were used only 17 million gallons in US (Huenteler et al., 2014).

Despite the fact that analytics predict the dominance of advanced biofuels in the future and agree that 1G biofuels have limited capacity to replace fossil fuels, for today volumes of 1G biofuels production increase. Taking in consideration that it will take significant amount of time for advanced biofuels to capture the market (with existing capacity, prices and technologies), it will be still valuable to concentrate analysis on 1G biofuels.

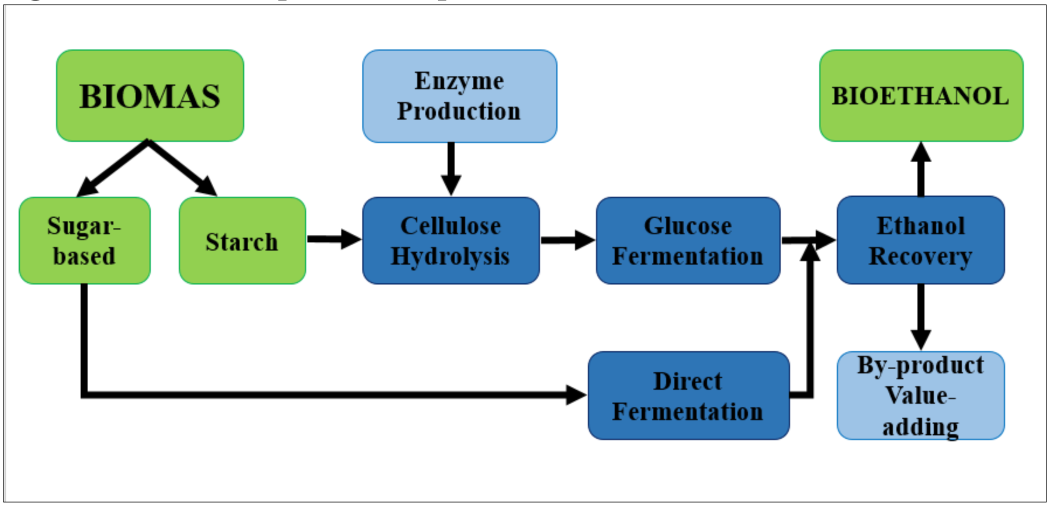
3.1.2.1 Bioethanol.

General definition of bioethanol is “ethanol produced from vegetative biomass through fermentation” (Guo et al., 2015). It is important to distinguish the difference between ethanol and bioethanol as these two fuels are always mistakenly accepted as synonyms. Both of them are alcohol based fuels, however there are significant differences in the production technology.

Ethanol, which is produced in large amounts around the world (mostly South Africa and Saudi Arabia), is a petroleum product. It is made by the hydrolysis of ethylene (ethylene + H2O), a major petrochemical (Tamers, 2006). Petroleum-derived ethanol (synthetic ethanol) is a widely used industrial solvent and has a considerable variety of other applications. The only, but significant difference between ethanol and bioethanol is that synthetic ethanol comes from fossil raw materials and bioethanol is derived as a result of vegetative biomass fermentation. (Tamers, 2006). That is why only bioethanol can be considered as a renewable green fuel.

On the Figure 3 it can be seen that sugar-based bioethanol production is easier, than starch-based production. In the first case bioethanol is derived directly by the process of fermentation using several species of yeast. The most widespread feedstock used to produce bioethanol around the world and particularly in Europe for today is corn (Ho et al., 2014), (European Renewable Ethanol, 2015). Fermentation of starch-based biomass is more complicated, because starch should firstly be hydrolyzed to fermentable sugars by enzymes. (Lin, Tanaka, 2006). Starch-based production is more energy demanding and more expensive.

Figure 3 Bioethanol production process.



Source: GNS Science, 2009; own computation.

In 2014 total world bioethanol production was 24570 millions gallons which is around 773,7 million tons (Renewable Fuels Association). Global fuel bioethanol production had grown for 7% as a result of declined production costs: good corn and sugarcane harvests and significant decline of crude oil prices. According to the REN21 (2015) the United States produced around 58% of all bioethanol, followed by Brazil (28%), China (3%), Canada (2%), and Thailand (1%); the European Union accounted for 6% of global production, led by France and Germany.

Bioethanol can be used directly as a fuel or blended with petrol. E85 which stands for 51-83% of bioethanol depending of the region and weather conditions and can be used only in flexible fuel vehicles. Intermediate blends such as E20 and E30 contain 20% and

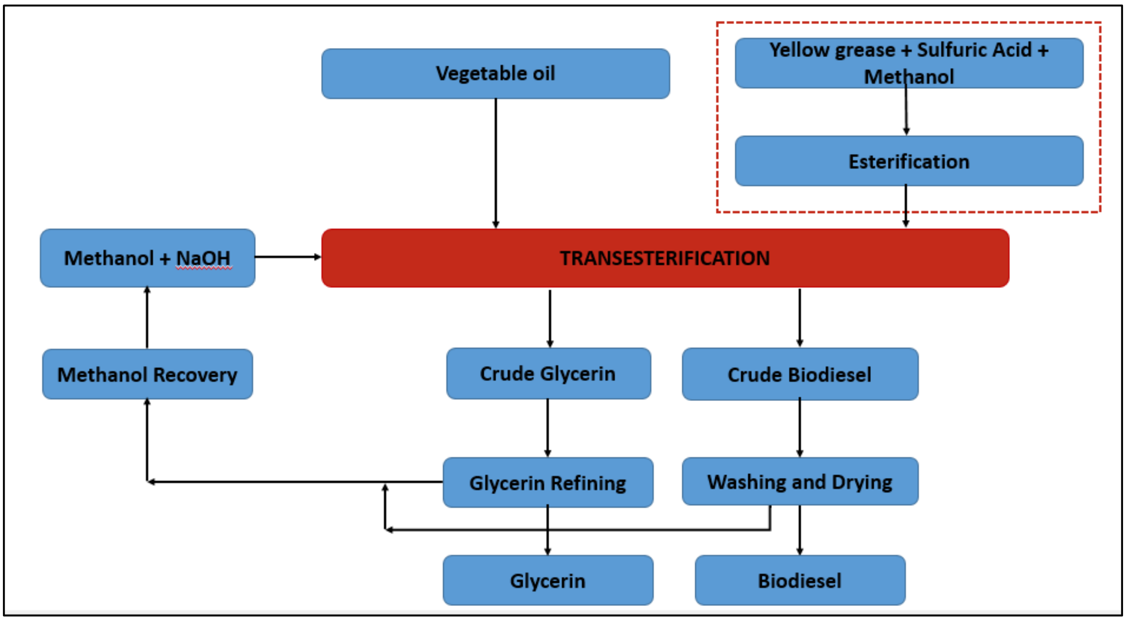
30% of bioethanol respectively. E10 and E15 are low-blended fuels and usually are not considered as a an alternative fuels (Alternative Fuels Data Center, 2014). All of these blends allow to decrease the side effects of fossil energy use. For example, Ho et al., (2014) mention that E10 alone reduces the usage of petroleum for 6%, decreases GHG emissions for 2% and cuts fossil energy use for 3%.

3.1.2.2 Biodiesel.

In order understand what is biodiesel, it is necessary to mention diesel definition. Diesel is a liquid hydrocarbon fuel produced form petroleum by fractional distillation (Guo et al., 2015). Fractional distillation is a process of mixture (crude oil) separation into different components (fractions). One of crude oil fractions is diesel oil (BBC, 2014).

On the contrast, biodiesel is a yellow liquid fuel derived from biomass (vegetable oil, animal fats, algal lipids or waste) by the technology of transesterification (Guo et al., 2015). Production process of biodiesel is illustrated of the Figure 4. The main purpose of the transesterification is to lower viscosity of the vegetable oil. It allows transforming the large molecule structure of vegetable oils to straight structured molecules that can be used in the typical diesel engines (Demirbas, 2008). It can be seen that during the production of biodiesel there are also side products such as soaps, which can be removed by the washing a drying process and then reused.

Figure 4 Biodiesel production process.



Source: Guo et al. (2015); own composition.

As well as bioethanol, biodiesel is also blended in proportions with diesel fuel. The most frequent blends are B100 (pure biodiesel), B20 (20% biodiesel, 80% petroleum diesel), B5 (5% biodiesel, 95% petroleum diesel) and B2 (2% biodiesel, 98% petroleum diesel) (Alternative Fuels Data Center, 2014). Pure biodiesel can be used in all vehicles that work on diesel; however, there are some limitations on the temperature conditions.

In general, biodiesel production uses mainly on vegetable oils of rapeseed in Europe and soybeans in United States and Brazil and palm oil in Indonesia. China also uses different side products such as used cooking oils and animal fats. REN21 (2015) sites that world production of biodiesel increased 13% to 30 billion litres. Europe in 2014 was the leader producer of biodiesel and counted for 39% of all biodiesel production and showed a 9% growth comparing to 2013 (REN21, 2015). The United States count for 16% of the world total, Brazil and Germany together – for 11%, Indonesia – 10%, and Argentina – 9.7% (REN21, 2015).

To summarize, bioethanol and biodiesel are the most used biofuels around the world according to statistics. The high speed of industry development was due to the oil crisis in 1970s and increased government support during 2000s. Despite the fact that 1st and 2nd generation biofuels industry show growth, there are issues that should be taken in consideration while building the strategy of development.

3.1.3 Benefits and challenges of biofuels.

Bioethanol and biodiesel of all mentioned generations have advantages and disadvantages that stimulate new research projects to create cheaper and more effective renewable fuels that can be used worldwide. Table 1 illustrates most common benefits and challenges of 1st and 2nd generation biofuels that are discussed among scientists and policymakers.

One of the reason why first generation biofuels market is growing is that there is already a *well-known production technology*. It is less time- and other resources consuming to build a new factory or expand the existing one. Advanced biofuels consume more investments in the implementation of the complicated technology. For example, Leite et al. (2013) mentions difficulties connected to the harvesting of algal and microalgal cultures that are used as non-food biomass material for 2G biofuels production. The task is challenging because these micro pieces can not be reached as easily as common vegetable oil plants, as well as the fact that algals are very thin therefore the process of harvesting should be very gentle.

The second benefit of 1G biofuels grows from the mentioned first reason. If there is already a clear technology of production, then production costs are lower and more production facilities can be build. This stimulates the growth of *commercial use*. Many advanced biofuels are now on the pilot stage and are not produced commercially due to high production costs. Despite that there are already several factories around the world that started to produce 2G biofuels, the production amount still remains very low comparing to 1G industry and it will take time to develop the market.

Table 1 Benefits and challenges comparison analysis of 1G and 2G biofuels

Benefits	**1G**	**2G**
well-known technology	+	-
commercial use	+	+/-
can be price competitive to petroleum	+/-	-
decreases GHG emissions	+/-	+
renewable raw materials	+	+
rural development	+	+
reduce dependence on fossil fuels	+	+
third countries development	+	+
uses non food biomass	-	+
Challenges	**1G**	**2G**
land and crops demanding technology	+	-
food prices correlation	+	-
high government support needed	+	+
emissions decrease may be eleminated	+	-
massive water usage	+	+/-
new difficult technology	-	+
low rate of commercial use	-	+
not price competitive with petroleum	-/+	+

Source: Leite et al. (2013), Ajanovic (2011), Abdelaziz et. al (2013), Bellof et. al (2014), own composition.

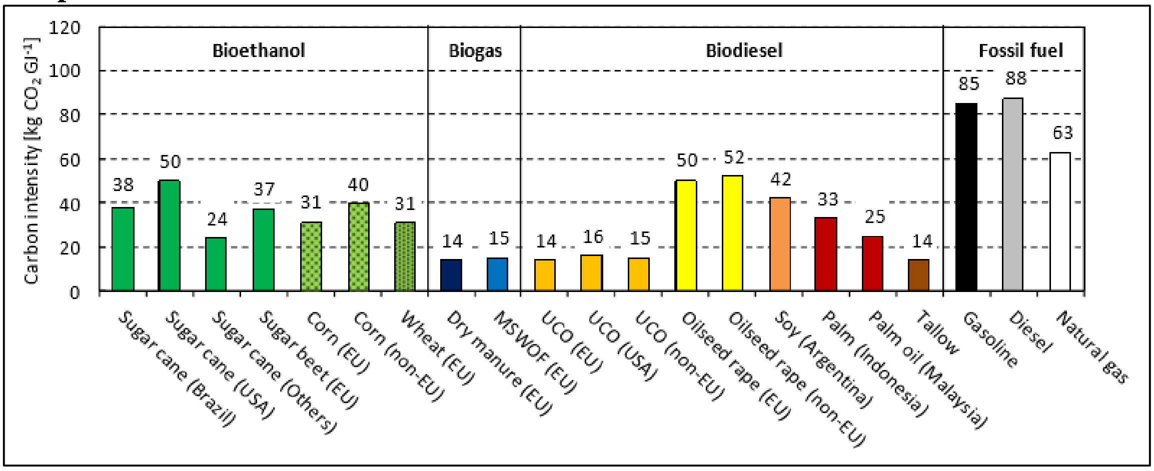
The question of *biofuels' price competitiveness* with petroleum is widely discussed among economists. Biofuelsforeurope.eu (2015) in the report "Competitiveness: Biofuels vs Petroleum-based fuels" mention that advanced biofuels can be competitive to fossil fuels only with technology development, large scale production and oil price around 60-170 USD per barrel. Further more, they write that at a lower price of 60USD per barrel competitiveness is possible only for 1G biofuels in a perspective of 2020-2030. Other researchers, such as Ajanovic (2011), Abdelaziz et. al (2013), Bellof et. al (2014) concluded that overall according to production cost scenarios 2nd generation biofuels are planned to be more competitive than 1st generation biofuels. Stephen et al. (2012) conclude that "in order for second-generation bioethanol to compete with first-generation bioethanol, large cost reductions must occur in a number of areas, including the capital and operational costs of most of the units" within technological chain. Recent trend of dramatic decline of crude oil price, which now costs around 23-24 USD per barrel (Bloomberg, January 2015), rises many questions on how the competitiveness of biofuels will be influenced.

Greenhouse gas emissions reduction is considered as one of the most important strategic reasons of biofuels industry development. Many researchers (Sims et al., 2008; Eijck et al., 2014; Burkart and Mayfield, 2013; Chen et al., 2014; Raboni et al., 2015; and others) mention the potential of biofuels to reduce GHG emissions.

Figure 5 shows evidence on the positive (to some extent) influence of different feedstock biofuels to carbon intensity decline comparing to fossil fuels usage. Biofuels produced from waste (UCO, MSWOF, tallow and manure) show the best positive results (Raboni et al., 2015). Piroli et al.(2015) mention two main channels through which the use of biofuels may reduce CO2 emissions:

1. *Fuel substitution effect*. This effect occurs when fossil fuel is replaced by biofuels on different markets.
2. *Consumption effect*. "Greenhouse gas emissions may be reduced if price increase caused by biofuels leads to a decrease in the agricultural commodity demand for food and feed. CO2 absorbed by crops dedicated to food and feed production is not isolated because people and livestock eat and release CO2" (Piroli et al., 2015).

Figure 5 Carbon intensity of biofuels resulting from different feedstock and technology, compared to traditional fossil fuels.



Source: Raboni et al., 2015

However, on the figure it can be seen that several biofuels such as biodiesel made of oilseed rape and soy and corn, sugar cane bioethanol do not show significant deduction of the carbon intensity in comparison to gasoline, diesel and natural gas. For example, some of the most toxic pollutants (e.g. benzene, 1, 3-butadiene, toluene, xylene) decrease when using bioethanol, others (e.g. formaldehyde, acetaldehyde, peroxyacetyl nitrate) increase (Raboni et al., 2015).

This insufficient reduction in GHG emissions by 1G biofuels are connected to several reasons: the usage of fossil fuels and fertilizers during production cycle of biomass, energy usage and emissions from the industrial conversion process, emissions from the final combustion of the liquid fuel (Sims et al., 2008).

Indirect land usage change also provokes GHG emissions increase (Sims et al., 2008; Piroli et al., 2015). Several papers prove direct effect of increased biofuels feedstock production to deforestation rate and resulting in release of carbon from forest soil and peat layers (HLPE, 2008; Havlik et al., 2011; Ciaian et al., 2013; Achten et al., 2013; and others). Some research show that the amount of GHG emissions from deforestation may be larger than the benefits of reduction caused by biofuels use. HLPE (2008) have used a worldwide agricultural model to estimate from land use change and concluded that "corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%".

Green paradox is another channel through which biofuels can increase GHG emissions (Sinn, 2008). Biofuel industry development can shift gasoline supply curve to the right as "owners of non-renewable resources worry about the rate of capital gains on these resources and thus are motivated to extract their stocks of oil more rapidly in order to convert a larger portion of their wealth into cash and securing it as financial capital" write de Gorter and Drebik (2011). The shift of supply curve provokes a decline of world gasoline prices, which then results in higher rates of consumption and higher GHG emissions (Piroli et al., 2015).

First generation biofuels made of feedstock increase the demand for energy crops and increase their price. As a result the same law as in green paradox works for the farmers' reaction to higher crop prices. Farmers are motivated to accelerate sales by increasing harvests. They start to use more fertilizers, double-cropping, etc, which may as well increase greenhouse gases emissions (Piroli et al., 2015).

Although overall net change of GHG emissions due to biofuels introduction is still not clear, Piroli et al. (2015) conducted an econometrical research, where they estimated the impact of the increase in biofuels production on CO2 emissions. Economists concluded that in a medium and long-run period (1961-2009) biofuels largely reduce world CO2 emissions level, however they admit that in a short run emissions may increase temporally.

One of the most important benefits of 2G biofuels comparing to 1G is *usage of nonfood biomass*. Recently there have been significant amount of debates risen about correlation between first generation biofuels development and food prices increasing (Cobuloglu et al., 2015; Sexton et al., 2008; Demirbas et al., 2009; Ciaian and Kans 2011; Bolognini, 2015; von Braun, 2008). Global organizations, such as IMF and World Bank state that biofuels largely contribute to food commodities prices growth. According to IMF estimations around 70% of the increase in corn prices and 40% of the increase in soybean prices were provoked by the growing demand for biofuels; and World Bank argues that up to 75% of the food prices growth was due to bioenergy development (Ciaian and Kancs, 2011). World Bank report is based on survey of food prices from 2002 and 2008 and estimates that higher fertilizers and energy prices provoked an increase of food prices only for 15%, while biofuels expansion resulted in a rapid increase of 75% (Chakrabortty, 2008).

At the same time there are several researches who do not confirm the direct impact of biofuels expansion to the food prices growth, such as Ajanovic (2011), who writes that for now no significant impact of bioenergy production to feedstock prices can be confirmed and co-existence of biofuels and food production is possible, especially for the 2G and other advanced biofuels. Similarly, European Commission (2008) states that “the European Union currently uses less than 1% of its cereal production to make bioethanol. This is a drop in the ocean. It uses two-thirds of its rapeseed crop to make biodiesel, but in fact European rapeseed production accounts for about 2% of global oilseed demand.”

There is a strong reasoning laying under these concerns of rapid food prices growth. As the demand for food is in general inelastic, the most vulnerable parts of society, such as people with very low income are considered to be at the highest risk. Von Braun (2008) explains the connection between low-income groups of people and biofuels industry: poor people are impacted by biofuels as consumers of food and energy, as farmers producing agricultural commodities, and as workers in labor markets. From one hand, the increase in food prices will give a chance to poor farmers to gain, but from another, the majority of poor people, who are the consumers, will have to reduce the consumption and change their nutrition (von Braun, 2008). As biofuels remain one of the main strategy for reducing dependence on fossil fuels and improving environmental situation, policymakers should also pay significant attention to the food security questions and protection of vulnerable groups of population, therefore the question of biofuels role in food security should be as clear as possible.

Despite mentioned possible negative impact of biofuels to poor people, there is an opinion that biofuels can also help developing countries. According to Eijck et al. (2014) investing in feedstock production industry development may become a solid basis for profit on the growing biomass market inside and outside developing country as well as for new generation biofuels production when technologies become available. However, for now there is low probability that developing countries will be able to reach the level of technology development and investments needed for a large scale biofuels production, especially second generation.

To summarize, first generation biofuels were aimed to solve problems of highest priority for the nations: dependence of fossil fuels and decrease of ecological pollution. Opinions on the positive and negative influence of 1G biofuels expansion has been differed with time and debates are still active. The full costs and benefits of biofuels utilization are still unclear, yet the level of the world 1G biofuels production is growing. In order to estimate costs and welfare effects to maximum possible level, it is important to understand main factors that build demand and supply of biofuels in general and specifically in the Czech Republic.

3.1.4 Main factors of biofuels supply and demand.

Identification of the main builders of demand and supply of the bioethanol and the biodiesel have crucial importance in the analysis of the market effects. Estimation of those effects is possible by economic and econometric modelling, therefore factors that determine demand and supply of biofuels should be clearly stated before introduction to the model.

Factors influencing demand.

Price of biofuels. This factor has an opposite influence on biofuels demand as the higher is the price the less people will be able to afford using it.

Income. Income will have a direct impact to the biofuels consumption. The higher income is the more people will be able to switch to biofuels consumption from petrol/diesel.

Policies on biofuels consumption stimulation. Governments are motivated to increase the demand of biofuels as it will go along with their sustainability and strategic energy programs. The main instrument influencing consumption is blending obligations. This is obligatory percentage of biofuels mixed with fossil fuels. This obligations tent to increase with time and vary from country to country, for example, Czech Republic has obligatory 4.1% for bioethanol and 6% for biodiesel (Sims, 2011) and Russia does not have any obligatory blending requirements.

Price of substitute. This factor is one of the main problem for the biofuel market as biofuels are considered to be uncompetitive to fossil fuels. There is a positive correlation between price of petroleum and diesel and demand for biofuels: the cheaper is the gasoline the lower is biofuels consumption. Accordingly, governments are trying to solve this problem with different policies influencing the production costs of biofuels aiming to decrease the final price and make biofuels more competitive. This question was significantly important in past three decades and had become even more crucial with the new oil prices dramatic decline that started in 2014.

Number of cars using biodiesel and bioethanol. This factor has a positive correlation with biofuels consumption as the more there cars with engines adapted to bioethanol/biodiesel, the hire will be the biofuels consumption. Car producers now manufacture flex-fuel vehicles (FFVs) that can use petrol and biofuel blends, particularly E85. According to U.S. Energy Information Administration database (2015) number of alternative fuel cars in United States is slowly increasing from 128.66 millions in 2012 to 128.97 millions in 2015.

Population level has also positive correlation with the demand on biofuels. The higher is the population level, potentially the more will be the consumption of biofuels.

Factors influencing supply.

Theoretically, there are several main factors that heavily influence supply of the product or commodity:

- *Price of the product* (commodity). There is a direct relation between price of a product and supply as the higher will be the price, ceteris paribus, the more producers will be willing to sell the product.
- *Cost of production* (depend on production cost structure). Costs of input have an influence to the profitability of the supplier: the higher are the production costs the less will be the profitability (ceteris paribus). It means that less producers will

be willing to use their limited resource for the industry with low profitability, they will prefer to switch to more profitable areas.

- *Technological improvements.* This factor has direct influence on supply as it is connected to the production costs. The more updated is the technology the less costly will be the production, therefore it may increase productivity and/or profitability and attract new suppliers to the market. This factor is significant when the technology is already implemented to the commercial use.
- *Government policies*. Increase in taxation and/or decrease in subsidies support will negatively influence the quantity of supply; and vice versa lower taxation and/or subsidies in the industry will rise profitability and increase supply.

Biofuel prices tend to have a long term correlation with oil prices and energy crops prices according to the research of Merkusheva and Rapsomanikis (2014). They conclude that there is a relationship: according to estimations oil market acts like a dominant in a pair bioethanol-oil prices with bioethanol price adjusting to the trend that is determined by oil prices. This may be explained by the fact that energy crops depend on oil prices heavily and at the same time are one of the main factors in biofuels economy.

Ajanovic and Haas (2010) write that the most influencing factors on *biofuels production costs* are feedstock costs, investment costs, fixed and variable O&M (operating and maintenance) costs, distribution and retail costs and policies on taxes and subsidies. Biofuel and petroleum has some similar components in function in the supply chain, but unlike petroleum, biofuels have different structure. For example, petroleum is gained from point sources (drill shafts) and as high-energy density liquid can be carried over a long distance with minimum transport costs; at the same time biofuel is made of biomass which is located on wide areas, depends on season and requires significant collection and transport costs (Yue et al., 2014).

Prices of feedstocks have high volatility due to many factors that influence their level: harvest, fertilizers costs, oil prices, land costs, other capital costs. There is different data on the most used feedstock for bioethanol and biodiesel around the world. It depends on the agricultural portfolio of each region and trading structure among countries. For U.S. bioethanol remains the main used liquid biofuel, therefore one of the main factors influencing the supply of biofuel is corn (Sorda et al., 2010). European union produces more biodiesel than bioethanol, therefore the main factor for EU will be rapeseed. Meanwhile for the bioethanol production EU uses mainly maize and wheat (ePure, 2015). Czech Republic in particular concentrates also on biodiesel production (FAME) where the main feedstock is rapeseed, meanwhile the sugar beet is the dominant energy crop for bioethanol production (EAGRI, 2014).. According to the data of Agricultural Ministry of the Czech Republic (EAGRI, 2014) in 2013 there was produced around 104,5 thousand tons of bioethanol and 80,9 thousand tons were made of sugar beet. The second most widespread source for bioethanol in Czech Rebublic is corn (EAGRI, 2014).

Festel et al. (2014) mentions that overall production costs of biofuels can decline with time as there is an economy of scale effect and a gain of experience in *technology* usage. There are many R&D programs on the European and countries level that finance technological development of 2G and other advanced biofuels production. Despite first generation biofuels still dominate the market, main technological financing goes to advanced biofuels therefore 1G biofuels R&D is stagnating and it means that for now this factor has lower influence to the biofuels supply increase.

Government policies influencing supply of biofuels mainly concentrate on taxes and subsidies (Thuijl and Deurwaarder, 2006; Wiesenthal et al., 2009; Sorda et al., 2010; Linares and Perez-Arriaga, 2013; Marousek et al., 2015; and others). Sarda et al. (2010) also mentions more specific government interventions to biofuels production chain with support of feedstock crops, labor, capital and land as well as import tariffs that protect national biofuel producers.

It can be seen that biofuels demand and supply are effected by many factors that sometimes can have correlation between each other. One of the main specifics of the market is that the price, which in theory should be one of the main important factors, tent to be less important on biofuels market because of a very high subsidies that provide competitiveness to petroleum and diesel. The current trend of oil prices decline has a significant negative effect on the subsidies power.

Biofuels were invented to serve main purposes of decreasing dependence of fossil fuels, providing energy security and increasing ecological and social sustainability. Historic development of the biofuels industry revealed benefits and challenges that world is facing with green fuels expansion. Biofuels significance is difficult to overestimate. This industry allowed starting a way to sustainable liquid fuel that will be available worldwide. Main players of the market such as United States, Brazil, European Union and others create programs to maintain the expansion of green fuels industry. Yet, despite all existing positive effects, there are significant debates risen on the question of the main biofuels' side effects such as pressure on food prices, high subsidies and tax incentives, decrease of expected rate of GHG emissions reduction, etc. Some of these problems will be solved by commercial implementation of advanced biofuels. However, until the world production of second generation biofuels will be sufficient, there should be effective and transparent policies controlling 1G biofuels (as the most wide spread liquid green fuel) and aiming to decrease negative side effects of this industry. Leading countries producing and using biofuels have a long track of alternative energy policies including biofuels programs. There are as well benefits and challenges that countries are facing during implementation of biofuels policies, therefore it is crucial for main players to consider the sharing of policies best practices.

3.2 World Biofuel Policies: Example of United States, Brazil and European Union.

This part presents comparative analysis of the biofuels policies of the main countries and regions producing green fuel: United States, Brazil, European Union in general and the case study of biofuels market and biofuels policy of the Czech Republic.

3.2.1 Main aims and challenges of biofuel policies.

Energy sector is one of the most important strategic components of each country. Alternative energy sector grows very rapidly and biofuels market in particular. Developed countries have longer history of biofuels policies programs development, however, more and more developing countries put biofuels to the main list of aims.

Biofuel policies have three main objectives of green fuel promotion:

1. The need to *decrease dependency* on scares and expensive fossil fuels.
2. Improve the environmental situation by *decreasing GHG emissions* (especially by the pressure of the Kyoto Protocol agreements).
3. *Agricultural and rural development*.

Another important policy objective that is connected to biofuels promotion is the *control of resource allocation* on the biofuels market (FAO, 2008). In the case of completely free market conditions with no governmental regulation on the biofuels market, there is high possibility that resource allocation would not be in favor of green fuel industry. Low efficiency, high costs and lack of competitiveness first of all would force farmers to switch to more profitable agricultural production of food crops, the same would happen with the final user, who would prefer to consume petroleum or diesel instead of expensive biofuels. Yet as the biofuels industry is important for developed countries (developing countries also increase attention to it) governments have to interact into the market and use instruments to reallocate resources.

Building and implementing policies on biofuels market is a challenging task for the government. This market is characterized by low transparency, tight connections to agricultural market, low efficiency and high costs and other significant challenges. Therefore, policymakers should work on two directions: from one hand, the government should use available instruments to promote and develop green fuel industry; from another hand, policymakers should work on eliminating or decreasing the negative effects of the industry.

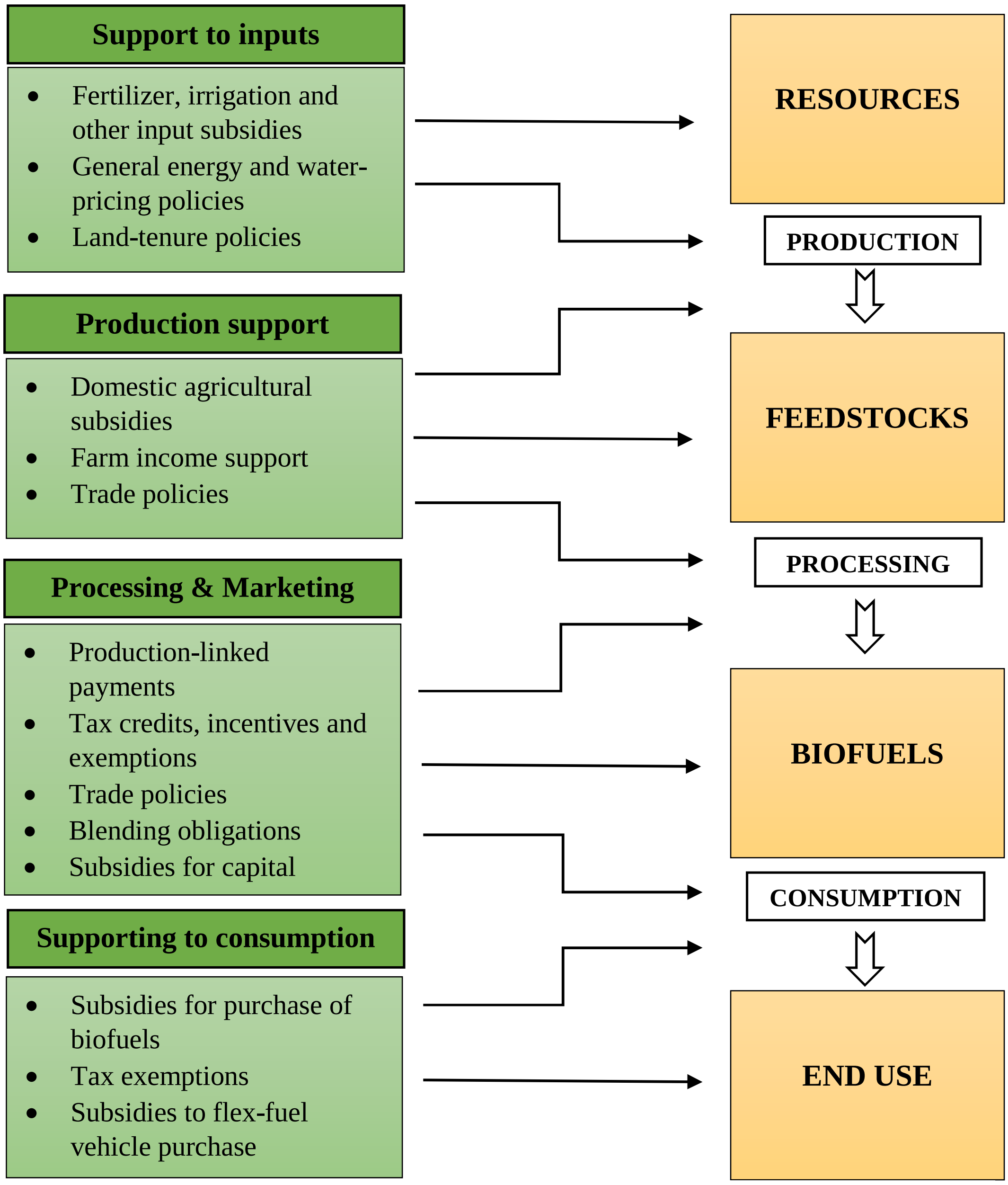
There are several kinds of policy instruments that are used on different stages of the biofuels production supply chain. Figure 6 represents support instruments that are usually used by the government during main stages of production and consumption. Land, fertilizers, water and energy are the main input resources. For example, fertilizers are one of the most expensive inputs, accordingly government provides subsidies to fertilizer producers in order to decrease the final price of the input. Government also can provide discounted tariffs for water and electricity usage for the farmers, producing energy crops as well as to biofuel producers.

Agricultural subsidies are well-known direct instrument that is used by majority of the countries. Farmers, who are producing the target product (in case of 1G biofuels it is energy crops), got subsidies to cover part of their costs. This instrument becomes a major stimulus for the farmers to switch from food crop production to energy crop production.

Farm income support is usually a number of direct payments to farmers and their partners that is provided if the farm is following certain conditions: producing beneficial product, follows rules of sustainable production, provides target volumes of production, etc. (Australian Government, Department of Agriculture and Natural Resources, 2014).

Governments use strong trading instruments to protect biofuels industry on the stage of production as well as on the stage of the final product. Despite the fact that most developed countries are now members of trading organizations, such as WTO and the rules of those organizations significantly limit the use of protectionist instruments, governments still use tariffs to protect their agriculture and biofuels sector (FAO, 2008).

Figure 6 Types of Support Along Biofuels Supply Chain



Source: FAO, 2008, own adaptation

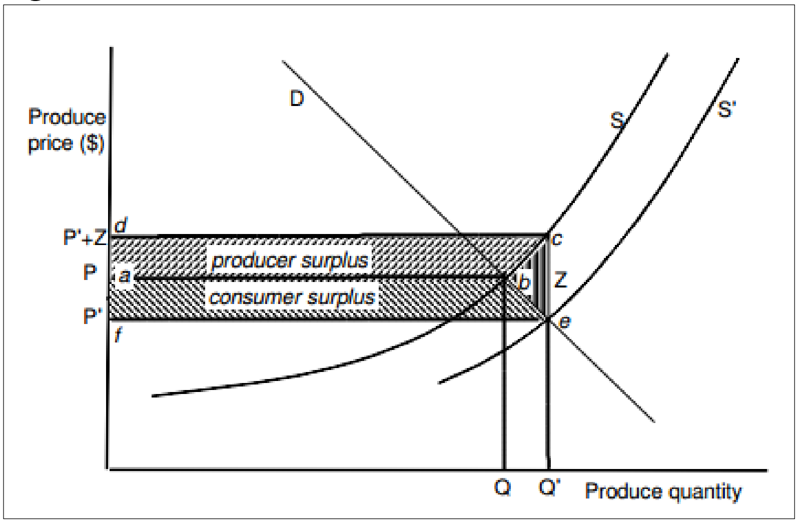
Tax incentives, tax credits and exemptions are also widely used instruments of biofuels industry support. These instruments are directed to the consumers of biofuels as they stimulate to use biofuels as an alternative fuel. Tax credits give the possibility to deduct specific amount from the tax payment in case of fulfilling approved target in biofuels consumption (Investopedia, 2016).

Blending obligations set up minimum quantitative target share that the producers of the final fuel should add to their final product. As already mentioned in the second chapter, there is a wide variety of biofuel blends on the market: bioethanol from 85% to 10% share and biodiesel from 100% to 2% share. Each country sets up blending obligations according to the biofuels policy goals and confirms these mandates by legislation. In the European Union each member should follow the common targets of blending shares.

Subsidies effects

Figure 7 illustrates the effect of production subsidy on the total welfare. It can be seen that the amount of the subsidy (Z) increases the effective producer price, therefore the supply curve shifts to the right with an increase of quantity supplied (Dorward, 2009). Subsidy implementation results in consumer surplus increase (trapezoid “abef” on the Figure 7) and producer surplus increase (trapezoid “dcba” on the Figure 7). These increases in consumer and producer surpluses are covered by the growth in the government expenditures connected to the subsidy implementation (rectangular “dcef”).

Figure 7 Subsidies effect on the welfare



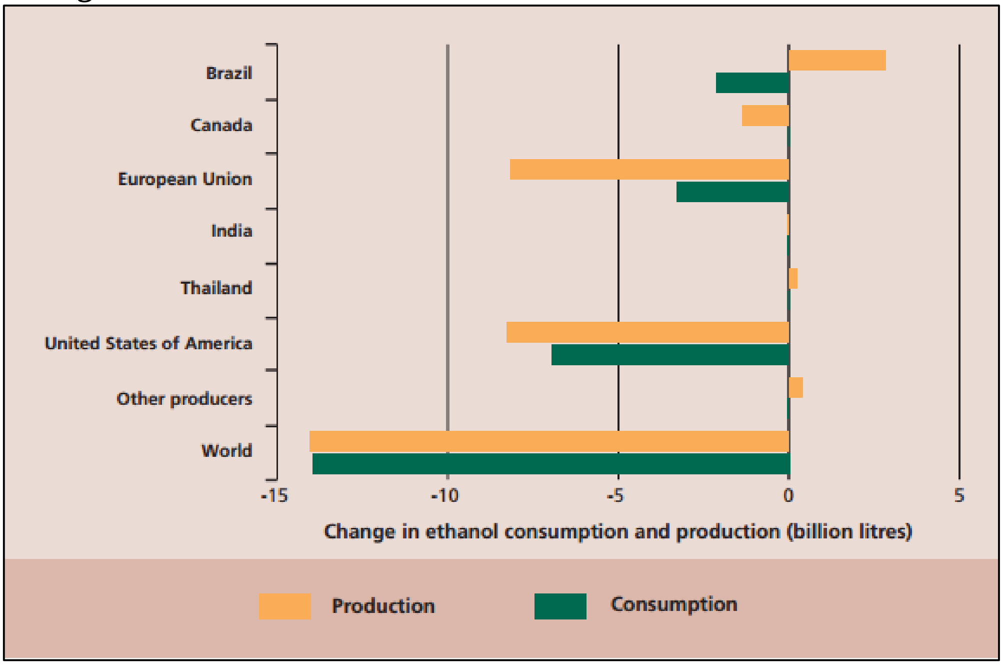
Source: Dorward, 2009

It can be seen on the Figure 7 that the area of government expenditures is higher than the areas of producer and consumer surplus increase. The difference is in the area “bce”, which represents the deadweight loss – the net economic loss of the country (Dorward, 2009). This theoretical example can be also applied to the biofuels market, where subsidies are used as the main instrument of production encouragement.

Economists argue that the best sustainable way to support biofuels industry is solving structural problems, such as financing research and development processes, supporting infrastructure development, etc. and direct instruments such should be removed (Sorda et al, 2010; Poonyth et al., 2004).

Food and Agriculture Organization of the United Nations in its report “THE STATE OF FOOD AND AGRICULTURE. BIOFUELS: prospects, risks and opportunities” (2008) publishes a research, which aimed to estimate the effect of direct biofuel policies elimination in OECD[1] and other countries. Figure 8 illustrates the estimated (for 2013-2017) influence of liquidation of direct biofuels policy methods to bioethanol production and consumption levels in different countries and regions.

Figure 8 Total impact of removing trade-distorting biofuel policies for bioethanol, average for 2013-2017

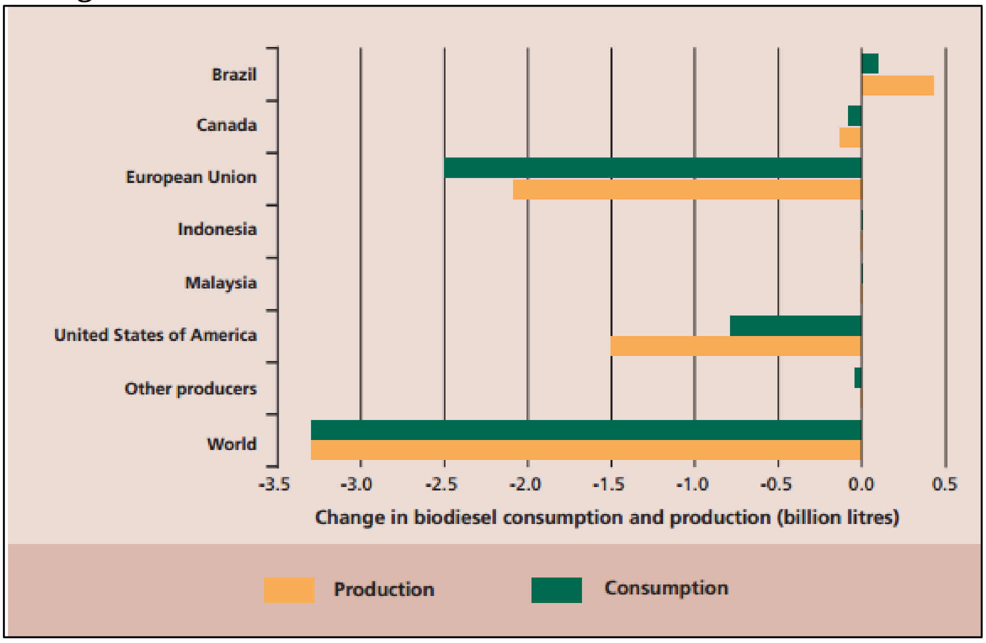


Source: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2008

It can be seen that the largest decrease of bioethanol consumption will occur in the European Union (as the government support in that region is one of the highest among all members) and in the United States. Brazil in contrary will increase bioethanol production (sugarcane bioethanol) as this industry is very developed and has relatively high efficiency. Overall world consumption and production of bioethanol will decrease for around 14 billion litres.

[1] OECD stands for the Organization for Economic Co-operation and Development, which aims to encourage sustainable policies to improve economic and social well-being around the world. In 2015 there were 34 countries – members registered. (OECD, 2016).

Figure 9 Total impact of removing trade-distorting biofuel policies for biodiesel, average for 2013-2017



Source: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2008

Figure 9 summarizes the results of direct support biofuels policies for biodiesel industry. The decline in production and consumption is also significant due to high dependence of this industry on subsidies. The European Union will suffer the most as its biofuels industry concentrates mainly on biodiesel production.

The results of FAO research show that biofuels industry according to their prediction is not ready for the elimination of direct support from the government and is too dependent on it. On the other side, keeping the biofuels sector on continuous financing does not contribute to the industry cost-efficiency. There should be a reasonable mix of direct and indirect instruments for the biofuel policies. Overall countries tent to use the same most popular instruments, yet there are sometimes significant differences in their structure. In order to build a clear picture of benefits and externalities of the biofuel policies it is important to examine the real examples of their implementation in main regions and countries-producers.

3.2.2 Biofuels policies in the United States, Brazil and the European Union.

Brazil, United States and Europe have common reasons for developing biofuels policies. Long historical track of biofuels industry development and rapid growth of the industry in last three decades require balanced, clear and consistent policies to promote and control biofuels expansion. Table 2 shows real examples of the instruments of biofuels policy that are used in the United States, Brazil and the European Union. The majority of authors mainly mention direct monetary instruments for the analysis. This leads to the conclusion that non-monetary indirect instruments are used rarely among countries.

Brazil.

Majority of authors (FAO, 2008; Sorda et al., 2010; Johnson, 2015) point out Brazil as a country with the most developed and successful policy of biofuels commercialization and promotion track. Intensive biofuels development started in 1970, when the oil crisis revealed shortcomings of oil dependence. Historically Brazil concentrated on the production of bioethanol from sugarcane rather than biodiesel. One of the first documents regulating biofuels market development was National Ethanol Program Protocol (Pro Alcool), introduced in 1975 (De Moraes, Undated). National program on bioethanol development aimed to promote the use of alternative fuel and adapt market for the massive bioethanol production. Therefore, government also made an important strategic step of making an agreement with main car producers for developing a market for modified vehicles long before the technology of flexi-fuel vehicles was presented (Sorda et al., 2010).

Implemented subsidies aimed to support target growth of the bioethanol industry for temporary period. However, after the second oil crisis the government had to prolong subsidizing. Deregulation policy was implemented from the beginning of 1990s aiming to support commercialization of ethanol industry: subsidies were illuminated. This step had a negative influence on the bioethanol production level, yet, the problem was partly solved by introduction of blending obligations of 20-22% for all petrol distributed around the country, later blending mandates were risen up to 25-27% (FAO, 2008).

Brazilian bioethanol was estimated as one of the most price-competitive biofuels on the world market (around $US 37) and its competitiveness remains even with oil price of $US 42 per barrel (de Almeida's et al., 2007), which would be important with the recent rapid depreciation of oil. Sorda et al. (2010) underline that such low price exists because of relatively low production costs, which are possible because of developed and cheap resource base of sugarcane and the fact that governmental support during infant stage allowed to save money for large investments to the research and development of the industry.

Despite the policy of liberalization, Brazilian government applied tax exemptions and tax incentives for ethanol industry (Table 2): bioethanol fuel has lower federal duties

(22% comparing to 47% for gasoline), VAT for bioethanol is 36% (for gasoline – 50%) and there is no excise tax for bioethanol fuel (de Almeida et al., 2007; Sorda et al., 2010; Johnson, 2015).

Biodiesel industry based on soybean, on the contrary to bioethanol liberalization policy, is supported by subsidies as infant industry. There are also significant tax incentives and exemptions from 73% up to 100% (Barros, 2014). Government as well uses imposed import tariff of 14% to protect biodiesel producers (Barros, 2014). Furthermore, in order to assure the target production levels the government organizes auctions where it buys given quantities of produced biodiesel.

Overall Brazilian policy on biofuels may be considered as successful. Government supported bioethanol industry during its early development and after liberalization created favorable conditions for the growth using direct and indirect methods (such as encouraging business networks among farmers). However, Stattman et al. (2013) write about several shortcomings of bioethanol policy such as: single crop focus that had a negative influence on agricultural diversification or dominance of large agribusiness companies and exclusion of small farmers from the production process. The research shows that there a lot of similar approaches between bioethanol and biodiesel policy, but the latter has faster development speed and there are chances that government will be able not to repeat the mistakes.

The United States of America.

This country as well as Brazil concentrated mainly on the bioethanol production based on corn. Main documents regulating the biofuel industry are: Renewable Fuel Standard (2010), Energy Independent and Security Act (2007) (Sorda et al., 2010). U.S. implemented financial encouragement programs after the first oil crisis as well as did Brazil. There was tax exemption for bioethanol blended fuels 100% of petrol excise (FAO, 2008). Later the government created a Volumetric Ethanol Excise Tax Credit (VEETC), which gave 51% of tax credit for each (even imported) 3,785 liters (1 gallon) and later was extended for biodiesel giving a credit of $US 1 per 3,875 liters (1 gallon) (Sorda et al, 2010).

Government also used the instrument of blending obligations to promote the production and consumption of the bioethanol. According to FAO (2008), mandates firstly were imposed in 2005 by the Energy Policy Act and Renewable Fuels Standard for the content of 28,4 billion liters (7,5 billion gallons) by 2012. These blending obligations were extended to 34 billion liters (9 billion gallons) in 2008 and to 136,3 billion liters (36 billion gallons) by 2022 (FAO, 2008).

Table 2 Main Instruments of Biofuels policies in US, Brazil, EU.

Countries/ Elements	**United States**		**Brazil**		**European Union**	
	Bioethanol	Biodiesel	Bioethanol	Biodiesel	Bioethanol	Biodiesel
Main feedstock	Corn	soy bean	sugarcane	soy bean	sugar beet, cereals	rapeseed
Controlling programs	Energy Policy Act (2005), Renewable Fuel Standard (2010), Energy Independent and Security Act (2007)		National Ethanol Program Protocol, Agroenergy Policy Guidelines, National Program on Biodiesel Production and Usage		Directives 2003/30/EC, 2003/96/EC, 98/70/EC, Common Agricultural Policy, Renewable Energy Directive (RED), 20/20/2020 Package	
Subsidies	national and local level	-	cancelled in 90s	subsidized as infant industry	for energy crops on set-aside areas, 45 EUR / hectare	
Tariffs	2,5% ad valorem	-	-	14%	Anti-dumping duties	6,5% ad valorem
Tax incentives	to feedstock producers	-	federal duties 22%, VAT 36%		for the feedstock producers	
Tax exemptions	-	-	no excise tax for bioethanol	73%-100%	for the feedstock producers	
Tax Credits	51% per 3,785 liters	1 USD$ per 3,785 liters			-	-
Blending obligations	34 billion liters by 2008, 136,26 billion by 2022		20-25%	2-5%	Voluntary, for ex. Germany 2,8%	Voluntary, for ex. Germany 4,4%
Other instruments	grants for infrastructure development project of E85 production	-	-	auctions where government buys given quantities	production quotas, quotas based on GHG emissions saving, grants for capital costs of feedstock production	
Non-market instruments	education programs for farmers		Special programs for building business relations for farmers		education programs for farmers	

Source: FAO, 2088; Sorda et al., 2010; Linares et al., 2013; Barros, 2014; own composition.

As far as American bioethanol has cheaper import competitors (e.g. Brazil), the government imposed import system of tariffs: ad valorem duty of 2,5% and a tariff of $US 0,54 per each 3,785 liters (Kowplow and Steenblik, 2008). Important is that the U.S. government mixed import tariffs with blending obligations, because even when the producers are protected from the foreign competition, they still have to compete against substitutes on the national market.

As it can be seen from the Table 2, USA have a wide subsidies instrument for the national and local level. There are subsidies for the feedstock producers, subsidies for the production-related capital, as well as output-related subsidies that are directly paid to producers for target amounts of bioethanol production. There is also a wide system of subsidies for research and development, for the development of the infrastructure and support of flexi-fuel vehicles (FFV) market development (FAO, 2008).

In general, the U.S. biofuels policy tents to have the widest set of multi-level monetary instruments such as subsidies, tax exemptions, incentives and credits imposed on national and local levels. The policy is criticized for the enormous spending (around 16 billion $US yearly), which is stagnating the competitiveness of the national biofuels industry (Kowplow and Steenblik, 2008; Sorda et al., 2010). The government also uses non-monetary methods for biofuel industry maintenance such as educational programs for farmers. Overall, biofuels policy portfolio should be extended by wider set of indirect methods and simultaneously constricted by the decrease of monetary package. These steps will provide balance and build the solid basis for the industry independence.

European Union.

Biofuels policy was established in EU in 2003 and the main aim was to decrease GHG emissions. On the contrary to Brazil and the U.S., European Union biofuel industry is mainly based on the biodiesel production from rapeseed. Bioethanol industry has lower levels of production and the main feedstock it uses is corn and cereals (FAO, 2008).

Active promotion of biofuels in Europe started from the Directive 2003/30/EC, which set voluntary targets for member states of 2% for biofuels content by 2005, 5,75% - by 2010 and 10% fulfilled by 2020 (Sorda et al., Bourguignon, 2015). Member states were free to set their own targets within national energy and biofuel policies, for example Germany settled targets of 4,4% for the biodiesel content and 2,2% for bioethanol content.

Several countries imposed tax exemptions and tax incentives for feedstock producers. According to the common EU policy, state members should get the allowances for the tax exemptions given to the farmers (van Thuijl and Deurwaarder, 2006).

Most of EU state members use tariff instruments to protect national biodiesel producers. Import tariffs are introduced for the Most Favored Nations[2] (MFN) and are 6,5% ad valorem duty (see Table 2) for biodiesel (Sorda et al., 2008). EU also introduced anti-dumping duties for the bioethanol imported from the U.S., Indonesia and Argentina (Flach et al., 2014).

Common Agricultural Policy (CAP) played an important role in the biofuels industry development. One of the main reforms was assigning about 95% of set-aside land for crop feedstocks (Sorda et al., 2008). Those areas usually do not suit for food agricultural production, therefore government created an opportunity for farmers to use this land for the energy cops. There were several subsidies programs introduced in a frame of CAP, mainly for the feedstock producers using set-aside land: 45 EUR per hectare (FAO, 2008).

Biofuels also get indirect support from European policies on rural development as well as through user incentives. There are several educational programs for farmers as well as grants for capital costs coverage in case if the farmer decides to start biofuels feedstock production (FAO, 2008). User incentives give car tax reductions and free parking for eco-friendly vehicles and FFV, this instrument successfully works in Sweden (Wiesenthal et al., 2009).

Linares et al. (2013) mention three main problems of European biofuels policy. One of them is large amount of regulating documents and lack of harmonization between them. This problem complicates creation of clear policies on national levels. Researchers rise the question of goals settlement: whether biofuel industry growth should be equal for all member states or there should be correlation with their production capacities. Another question is customer preferences. The research from Germany showed that most part of the consumers prefer to buy low-blended fuel because they are concerned about the engine safety and about negative environmental impact of 1G biofuels delivered by mass media. Low competitiveness is also mentioned as one of the major problems, as the industry has significant monetary support from the governments.

To summarize, as well as other countries, European Union member states use many monetary supporting instruments with much lower amount of indirect methods. European Union have created significant legal base controlling biofuels industry development,

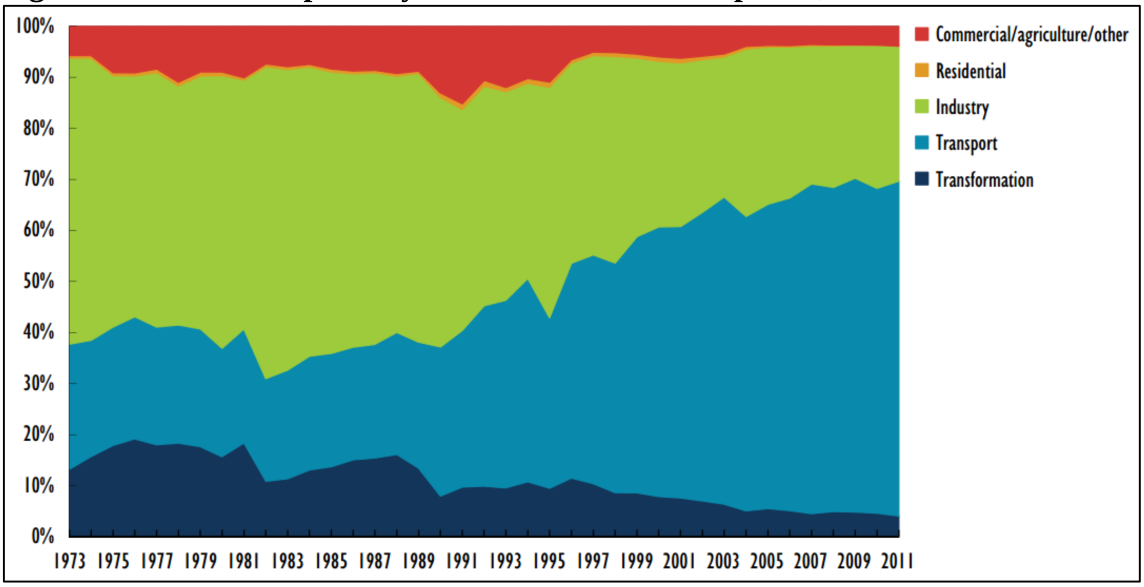
[2] According to WTO (Wto.org), MFN means that "every time a country lowers a trade barrier or opens up a market, it has to do so for the same goods or services from all its trading partners — whether rich or poor, weak or strong". https://www.wto.org/english/thewto_e/whatis_e/tif_e/fact2_e.htm

however the system of those documents is complicated and not clear for the implementation in member states. This is a challenging task to create a harmonized policy along all member states and it should become one of the main aims on the list. Until the policy on biofuels will grow to regional level from the local one and will be able to bring clear common goals, it will be hard to develop sustainable biofuel industry.

3.2.3 Biofuel policies in the Czech Republic.

The Czech Republic as well as other countries is facing several energetic challenges that are connected to the use of fossil fuels. One of the main is heavy dependence on the import of crude oil and petroleum. Czech Republic has a developed transport system and it consumes around two-thirds of all oil used in the country (IEA, 2014). The most used transport fuel is diesel due to its comparative lower price as a result of tax benefits from government. The Czech Republic has a wide trading network and its geographical location in the center of Europe and accession to the European Union provide significant increase in the level of heavy good vehicles resulting in higher demand for diesel (IEA, 2014). Figure 10 presents the structure of oil demand by sector of economy and it can be seen that transport demand has been increasing considerably from 1995 with the simultaneous shrinking of industry oil demand.

Figure 10 Oil Consumption by Sector in the Czech Republic, 1973 - 2011



Source: IEA.org, Energy Supply Security, Czech Republic, 2014

International Energy Agency estimates that more than 96% of all oil demand of the Czech Republic is met by imports from such countries as Russia, Azerbaijan and Kirgizia

(IEA, 2014). Therefore, this import dependence is a crucial strategic problem for the Czech Republic.

Another important goal for the Czech Republic energy sector is sustainable development. The Czech Republic, as well as other countries, has obligations for the GHG emissions decrease and is trying to find effective ways to fulfil this goal. Taking in consideration that the main demand for oil now goes from the transport sector, biofuels are one of the key ways to decrease the risk of energy dependence, increase self-sufficiency and decrease ecological negative effects of fossil fuels utilization.

According to the Ministry of Agriculture of the Czech Republic (2014), biofuels market of the country is mainly based on the biodiesel produced from the rapeseed. Bioethanol presents lower share of the market and is produced mainly from sugar beet and corn.

Jurčík (2015) writes that he first steps for complex biofuel policy were made in the beginning of 1990s with the program "Oleoprogram", which aimed to support the development of the biodiesel from rapeseed oil (rapeseed oil methyl esters - RME). "Oleoprogram" introduced financial support in the form of low or zero interest loans for the production startups. This program build a solid basis for the RME production growth in the Czech Republic: from 5 600 tons in 1993 to 27600 tons in 1997 (Czech Statistical Office, 2012).

The entrance to the European Union in 2004 brought significant challenges for the biofuels policy of the Czech Republic as well as for other new member countries. The majority of the problems were connected to the adaptation of legal base to the European standards. Furthermore, Europe had higher environmental requirements and the Czech Republic had to make costly investments in the development of new technologies and fostering biofuel market. Czech biofuels market was granted additional opportunities of support for the transition period connected to the EU entrance until 2006 (van Thuijl and Deurwaarder, 2006). In 2004 tax incentives were introduced in a form of lower excise duties for the fuel blends with biodiesel.

The Czech Republic followed aims of the main Directives of The European Union on biofuels policy, but there were main Documents that were created on the local level in a frame of environmental and energy policies. The first one is Act N 86/2002, which main aim was to foster the air protection (Mikulasova, 2015). The second is Decree N 229/2004, which was created to control import of biofuels to the Czech Republic (Mikulasova, 2015). The third document was the Government Order N 66/2005, which created a basis for biofuels market liberalization based on the targets imposed by the European Union (EAGRI, 2014). Additionally the Czech Republic adapted EU RED Directive and applied main aims into the Act on Air Protection 201/2012 and Government Order 351/2012, where there were new targets for biofuels development presented: share of biofuels in general fuel mix was targeted at 5,75% by 2016, GHG emission decrease for 2% by 2016 and minimum emission savings from biofuels sector of 35% by 2016 (Mikulasova, 2015).

Despite the aim of biofuels market liberalization and the agreement of subsidies elimination by 2006, Czech Republic still have a wide program of financial biofuels support. The European Union settled significant debates on the subsidies programs on the Czech biofuels market: according to the data of the Ministry of Agriculture (EAGRI, 2014) overall financial support from 2010 up to 2010 was 3181,01 millions CZK (which is around 128,339 millions euro[3]). Furthermore, according to Organization for Economic Co-operation and Development (OECD, 2016) data there were tax incentives of 39,89 euro for hectoliter biodiesel and 47,46 euro for hectoliter of bioethanol. The debates were also aggravated by the fact that the company Agrofert – the biggest monopolist on the agricultural market – is owned by the Czech Prime Minister (Jurčík, 2015). The government was ready to eliminate the subsidies to biofuels sector in order to stop all the debates connected to political question, however in 2015 there was a decision of subsidies prolongation excepted (Ekonomika.idnes.cz, 2015).

Besides tax incentives and subsidies, the Czech Republic, as well as other member states, implemented set of blending obligations for biodiesel and bioethanol, which goes along with the aims of EU. Minimal biodiesel blending target was set on the level of 6% and 4,1% for the bioethanol (EAGRI, 2014).

Overall, the biofuel policy of the Czech Republic is heavily influenced by the EU Directives and main goals. Mikulasova (2015) underlines that Czech biofuels market still does not work on the full capacity and is not competitive. Van Thuijl and Deurwaarder (2006) criticize Czech biofuels policy system for high bureaucracy and state that too complicated system of taxation and overall business environment lowers the industry's attractiveness. Furthermore, the Czech biofuels industry has very low transparency with few

[3] 1 EUR = 24,786 CZK in the end of 2010. http://www.kurzy.cz/kurzy-men/historie/EUR-euro/2010/

historical data available, which complicates the analysis of this market. The government should develop more indirect instruments to increase the competitiveness of the industry. European Union critics on subsidies prolongation has legal issues as there were made several agreements on the common policies, however, taking in consideration that many other member states (e.g. Germany and France) still use monetary instruments to support their local biofuel markets, the pressure on the Czech Republic should be whether extended to all member states or closed.

There is an obvious consensus that biofuels are a strategic industry that will allow solving at least three main world problems: eliminate dependence on the oil and fossil fuels, decrease GHG emissions, improve ecological situation, and bring new opportunities for the agricultural and rural development. Advanced biofuels ideally should play the main role at the world biofuel market; however, there are still no clear technologies that would allow producing 2G and 3G biofuels commercially with at least the same price level as 1G biofuels to give a slight chance for competitiveness. So far, 1G biofuels are the main force and their utilization is connected to several benefits and shortcomings. Therefore biofuels policies have to work on two main directions: improve the control and performance of first generation biofuels and build favorable conditions for the development of advanced kinds taking in consideration previous policies mistakes.

Biofuels policies examples analyzed in this chapter showed that the most widespread instruments used for the biofuels market support are subsidies, tax incentives and exemptions, blending obligations and tariffs. Moreover, the support is given on all stages of biofuels supply chain from the feedstocks to the final consumer. Analysis showed that biofuels policies start to adapt and improve to solve mentioned shortcoming of 1G biofuels. For example, governments started to pay attention to the important problem of biofuels and food prices correlation, food land competition and implemented motivation programs for the use of set-aside non-food areas for energy-crops.

As already said there are many challenges for biofuel policies now, but there are things that can be done to increase the their effectiveness. First, all policies should set clear, realistic and goals and use flexible instruments to fulfil those goals. Now most of the policies tent to be very ambitious, which does not help to build sustainable goals.

Second, national and local policies should be harmonized and have common transparent system of goals and instruments. The main example here is the European Union and its member states. The EU biofuel policies should be constructed taking in consideration capabilities and peculiarities of each member state, as this will help to increase effectiveness within member states and result in overall regional positive effect.

Third factor is technology investments and improvement of biofuels market infrastructure. These investments will have indirect development effect, but will help to increase competitiveness of the biofuels. Governments should also closely work with car producers and include this industry into biofuel policies targets. Several motivational instruments can be used, such as tax incentives, in order to increase the development of FFV production and their wider implementation to the market.

Policymakers also should pay close attention to consumers' motivation. Consumer education programs are crucial in order to build the positive image of the biofuels and decrease common doubts on the engine security problems, etc. Furthermore, the successful example of Sweden shows that such motivations as free parking for eco-friendly cars do work and should be considered for wider implementation.

The last important recommendation is given by Linares and Perres Arriaga (2013). They write that biofuels overall cannot solve all our problems with food prices, land competition, rural development, etc. There should be other policies (agricultural, ecological, rural, etc.) that will be harmonized with biofuel policies.

The Czech Republic is not an exception in the case of biofuels policies problems. The main shortcoming of the policy is the significant financial support that has a track of more than fifteen years. Subsidies do play a key role in the Czech biofuels market development, but at the same time they have negative influence on tax payers welfare, consumers welfare and overall welfare of the country. This negative effect is also supplemented by all other mentioned disadvantages of biodiesel and bioethanol utilization. From the other side biofuel industry plays important role in the rural and agricultural development. This industry creates working places and should have as well a positive influence to the total welfare of the country. Therefore, the question of positive and negative effects of biofuels industry in the Czech Republic is not clear. Next chapter presents preliminary research with estimations of the costs and benefits of bioethanol and biodiesel utilization in the Czech Republic.

4 Cost-Benefit Analysis of the Biodiesel and Bioethanol Utilization Contribution to the Welfare of the Czech Republic

This chapter will present the preliminary research, which aims to estimate the positive and negative influence of the biodiesel and bioethanol utilization in the Czech Republic. This research will be based on the analysis of the demand and supply curves of the biofuels (biodiesel and bioethanol) in the Czech Republic market. The analysis will allow to estimate consumer and supplier surplus and loss, as well as the loss for the government that occurs after subsidies implementation. These estimations will provide basis for the conclusions on the effect of the biodiesel and bioethanol utilization to the total welfare of the country.

4.1 Data introduction and modification.

Biofuels market of Czech Republic lacks transparency and it results in a shortage of data available for the analysis, which influences the model quality. Main sources of the data for this research are Czech Statistical Office, web source Kurzy.cz and Ministry of Industry and trade.

The model uses 60 monthly observations from January 2010 to December 2014. The basic data set of time-series is presented in the Appendix 1 and includes: combined production of biodiesel and bioethanol (tons), combined consumption of biodiesel and bioethanol (tons), subsidies amount (million CZK), price of rapeseed (CZK/ton), price of sugar beet (CZK/ton), bioethanol price (CZK/ton), biodiesel B100 price (CZK/ton), average salary (CZK), diesel fuel price (CZK/ton), gasoline price (CZK/ton) and blending obligations (%).All monetary units were deflated with consumer price index (CPI). Variable were given shortened codes in order to simplify the usage in the model.

Table 3 summarizes all variables that are included in the model and their shortened names (codes). Taking in consideration that the model aims to describe the market of biodiesel and bioethanol together, bioethanol and biodiesel price were combined in mixed biofuel price indicator (CZK/ton). Prices were mixed according to the weights of separate biodiesel and bioethanol production in the total biofuels production. The same principle was used for the modification of separate resource prices in mixed resource price indicator (CZK/ton) and modification of fossil fuels in a mixed fossil fuel indicator (CZK/ton).

Table 3 Variables summary

Variable name	Units	Variable code
Production	tons	Prod
Consumption	tons	Cons
Mixed biofuel price	CZK/ton	BFPr
Mixed resource price	CZK/ton	ResPrice
Mixed fossil fuel price	CZK/ton	FFPr
Average salary	CZK	AvSal
Subsidies	million CZK	SBSD
Blending obligations	%	BlObl

Source: own computation

4.2 Economic models.

Estimated model of supply and demand of biofuels in the Czech Republic should go along with economic theory. Therefore, it is important to introduce the economic model of supply and demand and make assumptions that are expected to fulfilled.

4.2.1 Supply economic model

Theoretically, supply function should be represented by the function where quantity supplied depends on the price of the product and factor of production costs:

Qs = f(P, W), where Qs stands for quantity supplied, P is a price of the product and W is the production costs factor (Epple and McCallum, 2005).

In the research the estimated supply depends on[4]:

- *Price of biodiesel and bioethanol*. Biodiesel price is presented by the price in CZK per ton of B100 fuel, which is pure biodiesel (Afdc, 2015). Bioethanol price is in CZK pet ton (Afdc, 2016).
- *Cost of production* factor is presented by rapeseed price (CZK pet ton), sugar beet price (CZK per ton) (Czech Statistical Office, 2016).

In the case of the Czech Republic biofuels market, there is a significant dependence of the supply on the amount of subsidies provided by the government (Mikulasova, 2015). Therefore, *subsidies* should be included to the model as one of the main factors of supply. Subsidies are presented in the model in millions of CZK (EAGRI, 2014).

Economic model of supply looks as follows:

Prod = f (BFPr, ResPrice, SBSD), where

Prod – quantity produced in tons

[4] See the Appendix 1 for the data set on supply function

BFPr – mixed price of bioefuels CZK/ton

ResPrice – mixed resource price CZK/ton

SBSD – amount of subsidies in million CZK.

Assumptions[5]

It is assumed that quantity supplied will have direct relation with BFPr, and SBSD variables: the higher are the prices of the product and subsidies, the higher should be the amount of supply. Subsidies are the main instrument used to support domestic biodiesel and bioethanol producers in the Czech Republic.

In contrast, variables connected to the costs of production should have opposite relation with supply quantity (Lin, 2011). The higher will be the prices of rapeseed and sugar beet (ResPrice) the higher will be the costs of production and as a result the lower profit: producers will decrease the production to decrease the costs or from the other hand, fewer producers will continue to produce with that amount of profit. In the current model it is also assumed that all amount produced is all amount supplied, therefore the variable Prod presents data of total biodiesel and bioethanol production in tons and is used as observation of the supply quantity.

4.2.2 Demand economic model

Liu (2011) uses price of the product and income as main factors of demand, Epple and McCallum (2005) add as well the price of the substitute product:

Qd = f(P, Y, S), where Qd is the quantity demanded, P is the price of the product, Y stands for income and S – substitute price.

Czech market biodiesel and bioethanol demand model is built with reference to the economic theory and practical issues connected to the biofuels market of the Czech Republic. Therefore, the main factors of the model are as follows:

- *Price of biodiesel and bioethanol*. Biodiesel price is presented by the price in CZK per ton of B100 fuel, which is pure biodiesel (Afdc, 2015). Bioethanol price is in CZK pet ton (Afdc, 2016).
- *Average salary* in CZK, which presents the income factor in the model (Tradingeconomics, 2015 and Stats.oecd, 2015)
- *Price of substitutes* is expressed through the price of the diesel fuel NAFTA in CZK per ton and gasoline price in CZK per ton (Kurzy.cz, 2016)

[5] All assumptions here and after are discussed with *ceteris paribus* condition.

The government regulates Czech market of the biodiesel and bioethanol. Particularly, demand is influenced by the instrument of the blending obligations, mentioned in the second chapter of this thesis. Accordingly, *blending obligations* for biodiesel and bioethanol should be included as factor in the model. This factor is expressed through the amount of percent that overall should be obligatory mixed with diesel and gasoline on the Czech market (OECD, 2016).

Based on the mentioned factors and on the data modifications, the demand model was constructed:

Cons = f (BFPr, AvSal, FFPr, BObl), where

Cons – amount of biodiesel and bioethanol produced in tons

BFPr – mixed biofuel price in CZK/ton

FFPr – mixed fossil fuel price in CZK/ton

AvSal – average monthly salary in CZK

BObl – blending obligations for biodiesel and bioethanol in %

Assumptions

It is expected that there should be positive relationship of biodiesel and bioethanol consumption with variables of substitutes' price (NAFTA and Gas), with average monthly salary variable (AvSal), with blending obligations (BObl) and import variable (Imp). An increase in each of these factors will result in the increase of the consumption. If substitutes become more costly, consumers prefer to buy the alternative product that will become relatively cheaper for them. When the average salary increases, more consumers are be able to switch to eco fuel. Growth in blending obligations results in increase in the consumption, because fuel companies are obliged to buy and add more biofuels to the fossil fuels.

Consumption will have negative dependence on the biodiesel (B100) and bioethanol (BEth) prices as the higher is the price the lower is the quantity demanded. It is as well assumed that all demanded amount of bioethanol and biodiesel is consumed, therefore variable Cons presents data of total biodiesel and bioethanol consumption in tons and is used as observation of the demand quantity.

4.3 Econometric model specification.

Demand and supply model is presented by the system of equations, which shows the simultaneous dependence of quantity supplied and quantity demanded on the price of the product (Majerus, 1982). Several researches write that while estimating the model of demand

and supply it is necessary to run a model *simultaneously*, because direct separate estimations of supply and demand will result in bias results (James and Singh, 1978; Majerus, 1982; Epple and McCallum, 2005; Lin, 2011; Liu, 2011). For this reason, the model of supply and demand of biodiesel and bioethanol in the Czech Republic is built using the two least square method (TLSM) (James and Singh, 1978; Woolbridge, 2009). The model is processed using Gretl software (Cotrell and Lucchetti, 2016).

Simultaneous econometric model of biodiesel and bioethanol supply and demand is presented as follows:

$$\begin{cases} Cons_t = \alpha_{1_1} K_t + \alpha_{1_2} BFPr_t + \alpha_{1_3} AvSal_t + \alpha_{1_4} FFPr_t + \alpha_{1_5} BlObl_t + \beta_{1_2} Prod_t + \varepsilon_{1_t} \\ Prod_t = \alpha_{2_1} K_t + \alpha_{2_2} BFPr_t + \alpha_{2_6} SBSD_t + \alpha_{2_7} ResPrice_t + \beta_{2_1} Cons_t + \varepsilon_{2_t} \end{cases} \quad (1)$$

where

α_{1_1}, α_{1_2}, α_{1_3}, α_{1_4}, α_{1_5}, α_{2_1}, α_{2_2}, α_{2_6}, α_{2_7} - structural parameters of each explanatory variable;

β_{1_2} , β_{2_1} – structural parameters of dependent variables;

K_t – constant;

ε_{1_t}, ε_{2_t} – error terms of each equation.

According to the assumptions mentioned in economic model description, it is assumed that in econometric model structural parameters α_{1_3}, α_{1_4}, α_{1_5}, α_{2_2}, α_{2_6}, β_{1_2}, β_{2_1} >0 and α_{1_2}, α_{2_7} < 0.

Moreover, structural parameters of the coefficient of biofuel price subsidies expected to have high significance, because the market is heavily subsidized.

4.3.1 Stationarity test and data modification.

Before running the regression it is essential to test the data set for stationarity. Time series are called stationary, when their probability distributions don not change over time (Woolbridge, 2009). If the probability distributions of the time-series changes in time (non-stationary data) then the model estimated through the OLS or TSLSM becomes biased (Granger and Newbold, 1974).

Gretl software allows testing time-series with constant only and with constant and trend. Therefore before the test is it important to look at the variable time-series plot in order to see if the constant and trend are presented there. As it can be seen on the time-series plots

(Appendix 2), all variables have constant and trend, except ResPrice and FFPr, which do not have a clear trend on the plot. Table 4 presents results of Dickey-Fuller test that is used as one of the possible test for stationarity.

Table 4 Dickey-Fuller test for non-stationarity results

Variable	p-value		α-level of significance	Non-stationarity hypothesis	Data transformation
Prod	0.5582	>	0.05	not rejected	YES
Cons	0.1839	>	0.05	not rejected	YES
ResPrice	0.1659	>	0.05	not rejected	YES
SBSD	0.5357	>	0.05	not rejected	YES
AvSal	0.00000007	<	0.05	can be rejected	NO
BFPr	0.2837	>	0.05	not rejected	YES
FFPr	0.2616	>	0.05	not rejected	YES
BlObl	0.5776	>	0.05	not rejected	YES

Source: own computation with Gretl Software

As it can be seen from the result of non-stationarity test, almost all data is non-stationary. That means it is not possible to use TSLSM until the data will not be transformed. Granger and Newbold (1974), Woolbridge (2009) discuss several methods of non-stationarity elimination: first-differences method, logarithm and introduction of seasonal dummy variables. All these methods were tested by the author, and method of seasonal dummy variables showed the best result for the model quality.

In order to eliminate time trend (non-stationarity) from the time series data, monthly dummy variables were included in both equations of the simultaneous econometric model:

$$\begin{cases} Cons_t = \alpha_{1_1} K_t + \alpha_{1_2} BFPr_t + \alpha_{1_3} AvSal_t + \alpha_{1_4} FFPr_t + \alpha_{1_5} BlObl_t + \beta_{1_2} Prod_t + \alpha_{1_8} D_2 + \cdots + \alpha_{1_{18}} D_{12} + \varepsilon_{1_t} \\ Prod_t = \alpha_{2_1} K_t + \alpha_{2_2} BFPr_t + \alpha_{2_6} SBSD_t + \alpha_{2_7} ResPrice_t + \beta_{2_1} Cons_t + \alpha_{2_8} D_2 + \cdots + \alpha_{2_{18}} D_{12} + \varepsilon_{2_t} \end{cases} \quad (3)$$

where $D_2, \dots, D_{12}$ are monthly dummy variables.

In this case dummy variable D_1 (January) is taken as a basis. Other monthly dummies take the value 1 only once per year according to the order and 0 in all other periods, for example D_2 has value 1 each year in February and in other months it equals 0 (see Appendix 4) (Woolbridge, 2009). After the model was transformed and the problem of non-stationarity was solved the TSLSM can be used as a method of biofuels supply and demand functions estimation.

4.3.3 Multicollinearity elimination.

It is important to check the variables for the multicollinearity – the correlation between two or more explanatory variables (Woolbridge, 2009, p 96). If such a correlation is present in the model, then the power of the estimation will be lower because the correlation between independent variable will add additional noise and decrease the strength of correlation with dependent variable.

Table 5 Correlation matrix of the supply-demand model

Variable	Prod	Cons	ResPrice	SBSD	BFPr	FFPr	BlObl
Prod	1	0.8715	0.1829	0.7740	0.4429	0.2645	0.5174
Cons	0.8715	1	0.3172	0.5519	0.8715	0.2244	0.4238
ResPrice	0.1829	0.3172	1	0,.2086	0.4307	0.5663	0.5112
SBSD	0.7740	0.5519	0.2086	1	0.6084	0.6284	0.8063
BFPr	0.4429	0.3453	0.4307	0.6084	1	0.4929	0.6313
FFPr	0.2645	0.2244	0.5663	0.6284	0.4929	1	**0.8014**
BlObl	0.5174	0.4238	0.5112	0.8063	0.6313	0.8014	1

Source: own computation, Gratl Software

Table 5 illustrates the correlation matrix of the supply-demand model. IT can bee senn that all correlation coefficients between independent variables within one equation are satisfactory, except the correlation between blending obligations (BlObl) and the mixed price of fossil fuels (FFPr), which is higher, than 0.8. It means that one of the factors should be excluded from the model. As far as BlObl have stronger correlation (0.4238) with dependent variable Cons, it is decided to eliminate FFPr variable with lower correlation (0.2244) with Cons.

After model modification, econometric model looks as follows:

$$\begin{aligned} Cons_t &= \alpha_{1_1}K_t + \alpha_{1_2}BFPr_t + \alpha_{1_3}AvSal_t + \alpha_{1_5}BlObl_t + \beta_{1_2}Prod_t + \alpha_{1_8}D_2 + \cdots + \alpha_{1_{18}}D_{12} + \varepsilon_{1_t} \\ Prod_t &= \alpha_{2_1}K_t + \alpha_{2_2}BFPr_t + \alpha_{2_6}SBSD_t + \alpha_{2_7}ResPrice_t + \beta_{2_1}Cons_t + \alpha_{2_8}D_2 + \cdots + \alpha_{2_{18}}D_{12} + \varepsilon_{2_t} \end{aligned} \quad (4)$$

4.3.4 Model identification

Before running the regression of both production and consumption functions function, it is important to check if none of these equations is not a linear combination of another (Čechura and Maier, 2014). Identification process is made separately for each equation. The condition of equation identification is:

$$k ** \geq \Delta G - 1 \quad (5), \text{ where}$$

$k**$ is number of predeterminant variables that are not included in the equation, but are in the whole model;

ΔG is number of endogenous variables in the equation.

For the *first equation* from the system of equations (4):

$k**$ = 2 as there are two predeterminant variables not included in the consumption equation (SBSD and ResPrice) and ΔG = 2, therefore we get 2 > 2-1, so the equation is identified.

In the *second equation* $k**$ = 2 and ΔG = 2, which means that we get the same results and the second equation is identified.

4.4 Econometric estimation of biofuels production and consumption functions.

In order to plot the supply and demand functions of biofuels in the Czech Republic, it is needed to estimate and built their functions econometrically.

4.4.1 Production function estimation

On the first step the production function was estimated using TSLSM and Gretl Software. The results are presented in the Table 4:

Table 6 Biodiesel and bioethanol production function estimation results

Variable	Coefficient	p-value	Significance
K	-3500.94	0.4736	
Cons	1.2137	1.61e-08	***
ResPrice	-1.05747	0.013	**
BFPr	0.26312	0.183	
SBSD	20.0582	0.3018	
D12[6]	-3862.76	0.0804	*
α-level of significance	= 0.05		R^2 = 0.84

Source: own computation with Gretl Software

The equation of the estimated production function looks as follow:

$$Prod = -3500.94 + 0.26312 * BFPr - 1.0547 * ResPrice + 20.0582 * SBSD + 1.2137 * Cons - 3862.76 * D_{12} + \varepsilon_{2_t} \quad (6)$$

The results of the production function regression differ from what have been expected. Assumptions of correlation direction and significance of the consumption (Cons) and resource price (ResPrice) were confirmed. The criteria of significance is p-value < α-

[6] D_{12} dummy variable is incuded in the model as it will be used later for the computation of supply and demand functions in December 2014

level of significance (Woolbridge, 2009), which in this case is 0.05. The highest significance belongs to the variable Cons, which shows tight dependence of the biofuels production on the biofuels consumption on the market. Additionally structural parameter of Cons variable is positive. This goes along with the theory as the higher is the consumption the more producers will be willing to participate in the production process as well as current producers will try to increase the supply. Estimation shows that with an increase in consumption for 1 ton, the production will grow for 1.214 tones. The fact that consumption grows for higher amount than the production may be explained by the presence of imported biofuels on the market or/and by the production surplus from the last periods.

Price of resources (RecPrice) structural parameter is negative and has relatively high significance. It was expected that the biofuel production will be higher with lower resource prices and vice versa. According to the estimation if the resource price will grow for 1 000 CZK, the production of biofuels will decline for 1.056 tons.

However, the structural parameter of the subsidies variable (SBSD) did not show any significance, which is very unexpected taking in consideration the real situation on the Czech biofuels market. This may be happened because of the small observations amount, which influences the quality of the model. This variable was decided to keep in the model due to its importance for the analysis and the fact that the sigh of the parameter meets the expectations.

The same happened to the variable of biofuels price (BFPr), which was supposed to be significant. This variable is crucial for the model because it will form the supply function for the supply curve plotting. Therefore, BFPr was also kept in the model because of its importance and the correct expected sign of the structural parameter. The correlation between production of biofuels and their price appears to be low in the model, however it may be explained by the significant influence of subsidies on the real life market. Producers still can increase the production with no relevance to the price if part of their costs will be covered by the subsidy (Dorward, 2009). Overall, it can be seen that the R^2 coefficient is 0.84, which means that chosen independent variables describe the dependent variable (Prod) for 84%. The quality of the model tents to be high, however it is important to make the econometric and statistical verification of the model in order to be sure that the results are not biased (Woolbridge, 2009; Charemza, 2003).

Production model tests for normality, heteroscedasticity and autocorrelation

Error term represents several things in the model. It can contain the omitted variables that were not included in the model, errors that were made during data observation (statistical noise) or errors connected with data estimation as well as approximation errors that appear as a result of unknown functional form of the equation (Woolbridge, 2009).

It is an important for the error term to have *normal distribution*. It means that the data used for the model do not have shock values and/or there are no signals of other problems with model assumptions (Woolbridge, 2009). *Heteroscedasticity* test shows if the error ε_t is changing in time. If the model is proved to have heteroscedasticity problem, then it means that the error terms are not possible to predict and estimate (Maddala, 1992, p 201; Woolbridge, 2009, p 264). Autocorrelation tests shows if the error terms correlate with each other in different periods of time, which will also influence the quality of the model and may make the results of estimation biased. If there is an autocorrelation in the model it means that the error term is not independent and there are some other factors influencing it (Maddala, 1992 p 229-230).

Table 7 illustrates the results of the test for normality, heteroscedasticity and autocorrelation. All the tests were held using Gretl Software. For all the tests the null hypothesis (Ho) was tested. According to the classic approach of hypothesis testing, Ho is accepted, when p-value of the test is higher, than the α-level of significance (0.05).

Table 7 Heteroscedasticity, normality, autocorrelation tests results for the production function model

Test	Ho	p-value	Result
Heteroscedasticity (Pesaran-Taylor)	heteroscedasticity not present	0.3739 > α	no heteroscedasticity
Normal distribution	error is normally distributed	0.1236 > α	normal distribution
Autocorrelation (LM)	autocorrelation not present	0.4158 > α	no autocorrelation

Source: own computation, Gretl Software

It can be seen by the test results that the model does not have any autocorrelation or heteroscedasticity and the error term has normal distribution. This allows to make assumption that the results of TSLSM estimation are not biased and are sufficient (Woolbridge, 2009).

4.4.2 Consumption function estimation

Consumption function was also estimated using method of TSLS in the Gretl Software. Table 8 shows the results of the estimation.

Table 8 Biodiesel and bioethanol demand estimation results

Variable	Coefficient	p-value	Significance
K	2524.73	0.8236	
Prod	0.618681	3.49e-010	***
AvSal	-0.893518	0.089	*
BFPr	-0.256476	0.0696	*
BlObl	3195	0.0099	***
D12	3962.55	0.0166	***
α-level of signif =		0.05	R^2 = 0.84

Source: own computation, Gretl Software

The equation of the estimated consumption function looks as follow:

$$Cons = 2524.73 - 0.256476 * BFPr - 0.893518 * AvSal + 3195 * BlObl + 0.618681 * Prod + 3962.55 * D_{12} + \varepsilon_{1_t} \quad (7)$$

Overall, the results of the demand function estimation go along with the theoretical assumptions. The production (Prod) has a very tight connection with the dependent variable (Cons). Structural parameter is extremely close to the 0 and thereore is very significant even at the level of significance α = 0.01. The parameter has positive sign, which means that with the increase of production for 1 ton, the consumption will increase for 0.619 tons.

Biofuel price mix (BFPr), on the contrast with the production function, is significant with α = 0.1. Its structural parameter has negative sign, which satisfies theoretical assumptions: the higher is the price of the product (biofuel) the lower is its consumption. According to the estimations if the biofuels price will grow for 1000 CZK per ton, the consumption of biofuels will decline for 0.257 tons.

Blending obligations present the factor of the government policy in the model. Estimation shows the high level of the parameter significance even at the level of significance α = 0.01. The character of the relationship is the same as in the assumptions: the higher are the blending obligations, the higher is biofuel consumption. If blending obligations (BlObl) will increase for 1%, the biofuel consumption (Cons) will increase for 3195 tons.

Average salary structural parameter showed a negative relation with the consumption, which goes against the theoretical assumptions. However the model shows the significance of the parameter with α = 0.1. According to the estimations with an increase of the average salary for 1 000 CZK, the consumption will decrease for 0.894 tons. This distraction in the model can be explained by the lack of available data to increase the number of observation, therefore the model have preliminary character.

Demand model tests for normality, heteroscedasticity and autocorrelation

Table 9 illustrates results of the model test for the error distribution normality, heteroscedasticity and autocorrelation.

Table 9 Heteroscedasticity, normality, autocorrelation tests results for the demand function model

Heteroscedasticity (Pesaran-Taylor)	heteroscedasticity not present	1.1964 > α	no heteroscedasticity
Normal distribution	error is normally distributed	2.2166 > α	normal distribution
Autocorrelation (LM)	autocorrelation not present	0.2096 > α	no autocorrelation

Source: own computation, Gretl Software

It can be seen from the tests results that econometric verification of the model is fulfilled and the model seems to be unbiased and sufficient.

4.5 Biofuels supply and demand curves

After the functions of production and consumption were estimated, it is possible to plot biofuels supply and demand curves. In order to build the curves the real observed values were put into the estimated equations (Apple and McCallum, 2005). The observations period is December 2014, which is the last period the estimated data set.

$$\begin{cases} Prod = -3500.94 + 0.26312 * BFPr - 1.0547 * ResPrice + 20.0582 * SBSD + 1.2137 * Cons - 3862.76 * D_{12} \\ Cons = 2524.73 - 0.256476 * BFPr - 0.893518 * AvSal + 3195 * BlObl + 0.618681 * Prod + 3962.55 * D_{12} \end{cases} \quad (8)$$

After solving the equation (8) the functions of supply and demand look as follows:

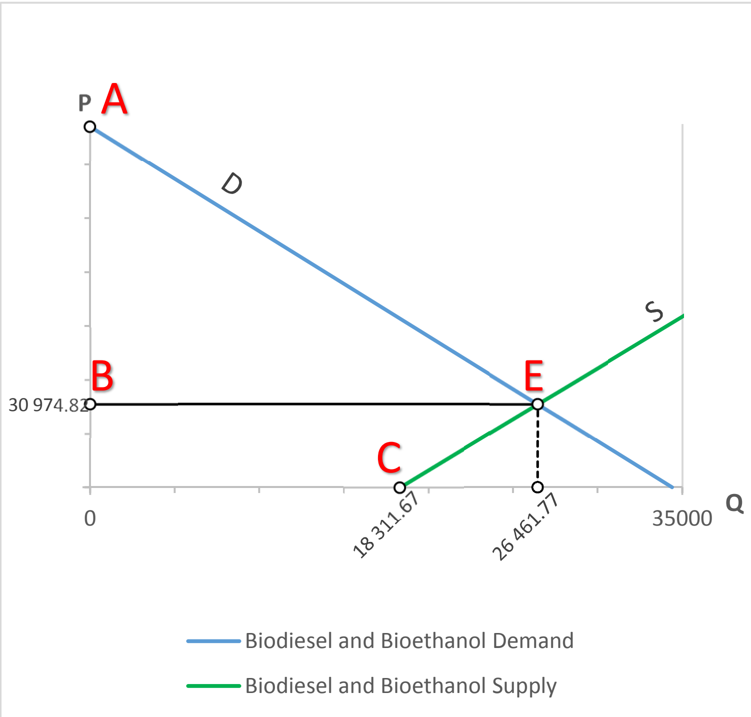
$$\begin{aligned} Qs &= 18311.67 + 0.26312 * BFPr; \\ Qd &= 34406.08 - 0.256476 * BFPr \end{aligned} \quad (9)$$

It is possible to plot the supply and demand curves of biofuels by calculating main points of the plot using equations (9).

4.6 Results and discussion

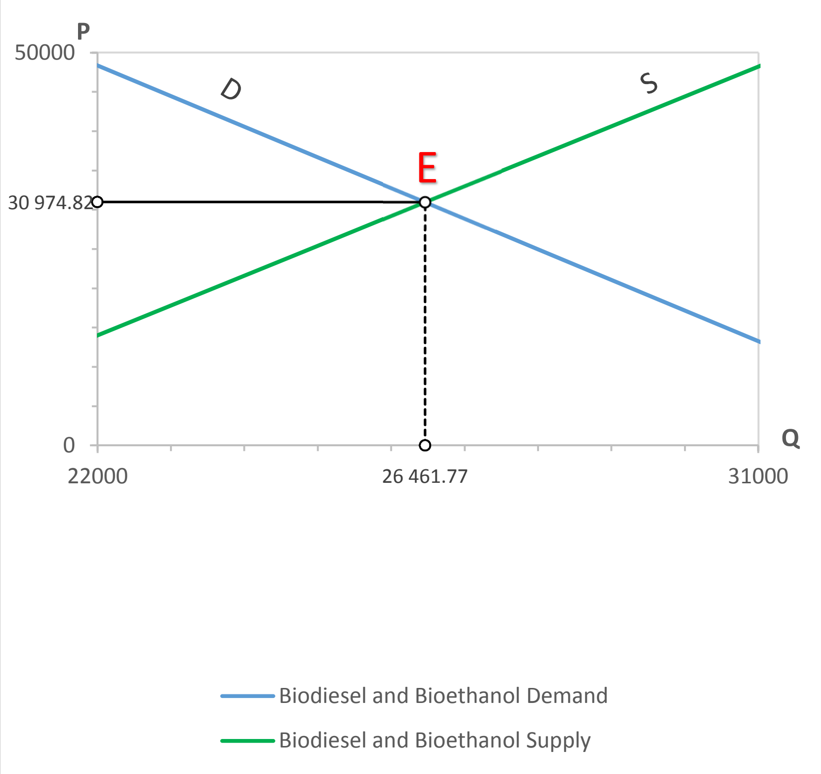
The Graph 1 represents the hypothetical modeled situation of equilibrium on the biodiesel and bioethanol market of the Czech Republic. Due to high values of intercepts in the equations the curves are significantly shifted to the right, therefore, scaled graph will be also used for illustrations. The estimated equilibrium price in the model is 30 974.82 CZK per ton, which is very close to the real observed value in December 2014 (28 687.18 CZK). Equilibrium quantity supplied and consumed at this price equals 26 461.77 tons (Graph 1 and 2). Consumer surplus in case of the modeled equilibrium is presented by the value of triangle ABE square and equals 1 365.09 million CZK. It can be seen on the Graph 1 that the producer surplus, which is presented by the value of trapezoid 0BEC square, is significantly smaller than the consumer surplus. Producer surplus equals 693.425 million CZK.

Graph 1. Modeled equilibrium on the biodiesel and bioethanol market of the Czech Republic, December 2014



Source: own computation, Excel

Graph 2. Scaled modeled equilibrium on the biodiesel and bioethanol market of the Czech Republic, December 2014

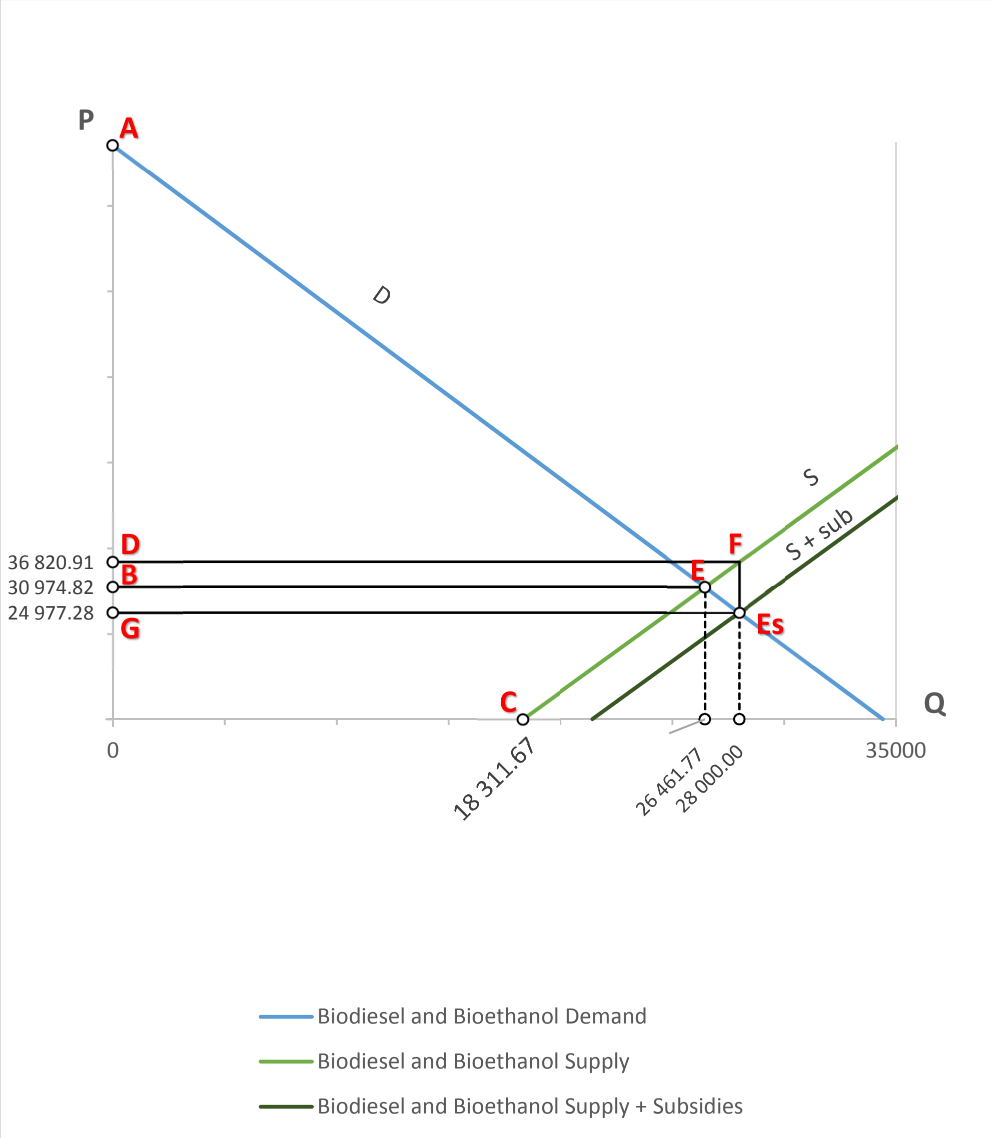


Source: own computation, Excel

Subsidies

The analysis of the subsidies effect is complicated, because the market is already built by the subsidy influence and as a result its structure is unclear. However, it can be assumed that the current situation on the real market is not the same as in modeled equilibrium (Graphs 1 and 2). The quantity of biodiesel and bioethanol produced in December 2014 was 28 000 tons, therefore it is assumed that the real supply curve should cross demand curve in the point, where Qs equals 28 000 tons. It may be also concluded that this shift of supply curve to the point of 28 000 tons was provoked by subsidies.

Graph 3. Subsidies introduction to the biodiesel and bioethanol supply and demand market in the Czech Republic , December 2014



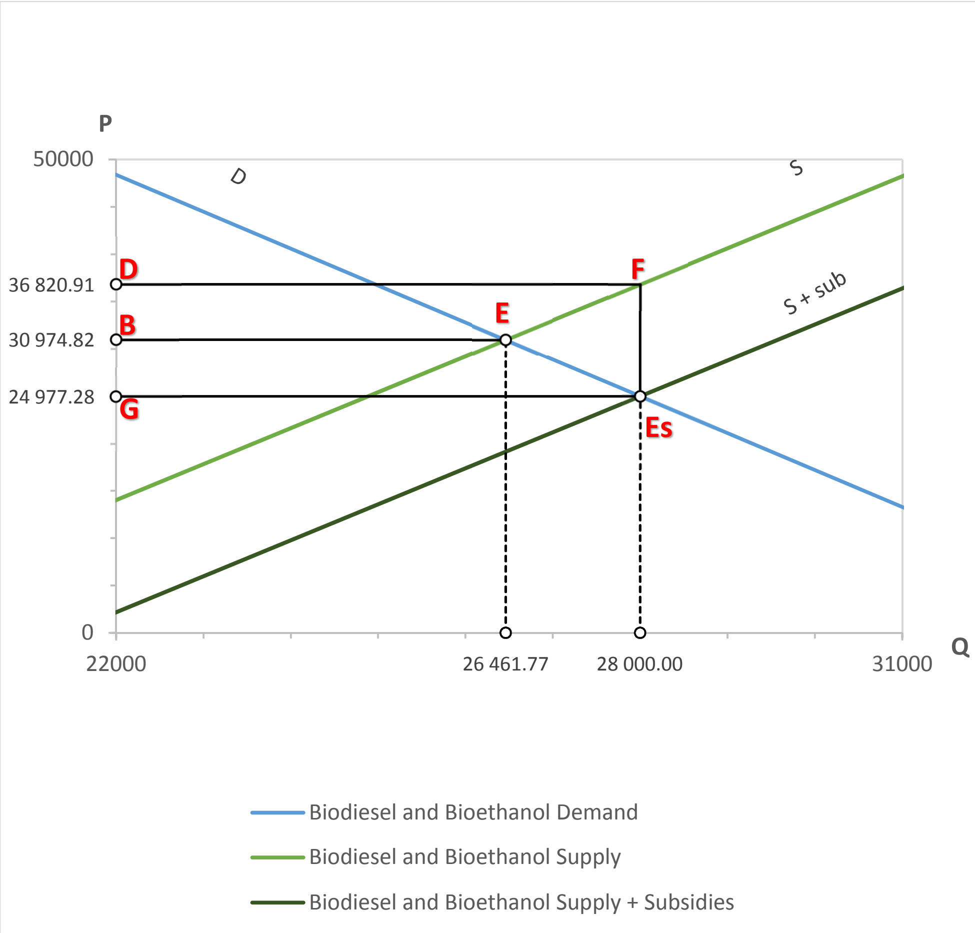
Source: own computation, Excel

It can be seen on the Graph 3 and 4 that the supply curve shifts to the right and now it crosses the demand curve in the new point of equilibrium Es. The quantity in the new equilibrium position equals 28 000 tons and the price 24 977.28 CZK per ton. This model illustration is controversial as from one hand the new quantity supplied is the same as on the real market in that period, from the other hand the equilibrium price that was formed by the supply curve shift in now lower, than the real price on the biofuels market of the Czech Republic. This inconsistence can be explained by the fact that curves are built from the estimated functions, the econometric model is preliminary and can be improved in the future.

Furthermore, the market is distracted by the subsidies; therefore, it is difficult to get precise estimations.

Due to subsidies the effective price (Dorward, 2009, p. 2) for the producers moves to the point 36 820.91 CZK per ton, however consumers are not ready to by 28 000 ton at that price. Graphs 3 and 4 illustrate the change in consumer and producer surplus. Trapezoid BEEsG (Graph 4) represents the increase in consumer surplus. The calculation of its square value gives the amount of 163.318 million CZK, which is around 12% growth of the surplus that consumers gained without subsidy on the market. Producer surplus increase is illustrated by the trapezoid BDFE and equals 159.194 million CZK, which is almost 23% increase in producer surplus before subsidy.

Graph 4. Scaled subsidies introduction to the biodiesel and bioethanol supply and demand market in the Czech Republic, December 2014



Source: own computation, Excel

These increases in the consumer and producer surplus were totally financed by the government. Total economic costs connected to the subsidy implementation are presented by the rectangular DFEsG. The value of its square is 331.622 million CZK. It can be seen on the Graph 4 that rectangular DFEsG is bigger than the sum of trapezoids BEEsG and BDFE, as it also includes triangle EFEs. This triangle represents the deadweight economic loss of the society due to the subsidy implementation and it equals 9.109 million CZK.

Overall, it can be concluded that the implementation of the subsidy provokes the net economic loss for the Czech Republic. This loss is connected to the income shift from the taxpayers to the producers and consumers of biodiesel and bioethanol in the Czech Republic (Dorward, 2009, p. 2). Furthermore, the loss also contains costs connected to the market inefficiencies that are associated with subsidies implementation, for example, ineffective allocation of the resources. Furthermore, this loss can become even bigger if environmental shortcomings of the biodiesel and bioethanol industry expansion will be added.

The research proved arguments stated in the theoretical framework. First of all, subsidies were proved to provoke economic loss, particularly in the Czech Republic market. Secondly, the biofuels market low transparency was confirmed by the difficulties with data mining during the research. As a result, the estimated model is preliminary and therefore considered not to be precise. Results are controversial. From one hand, all the verification tests proved that the model is unbiased and sufficient. Most part of the theoretical assumptions made before the estimation were fulfilled and go along with the economic theory. From the other hand, estimated values sometimes have significant differences with the real life observed values, for example in the case of total subsidies amount. Therefore, the author recommends to consider the results of the research, in particular the cost-benefit analysis, to have theoretical character.

The main recommendations that can be proposed based on the results of this research are as follows:

1. As the data analysis and model reveled the net economic loss provoked by subsidies, it is recommended to consider decreasing the amount of the direct financial support for the biofuel sector in the Czech Republic. It is clear that the full elimination of subsidies is not possible yet, because the market is not competitive. However, the share increase of indirect support use such as R&D grants, education of farmers and consumers, blending obligations, etc. may result in lower distraction effect for the market.

2. The Czech Republic government should consider the increase of investments in the R&D of advanced biofuels technologies development in collaboration with and financial support of the European Union. The advanced biofuels policy should not repeat the same mistakes of past.
3. EU and the Czech Republic should increase the cooperation on the improvement of biofuels market transparency.

5 Conclusion

In the last three decades biofuels market showed significant growth. The majority of biofuels, which are presented on the market, belong to the first generation biofuels. Considerable amount of the researchers discuss the question of 1G biofuels sustainability. This question is also unclear for the Czech Republic market.

This research meets the objectives of estimation the economic costs and benefits of biodiesel and bioethanol use in the Czech Republic and examination of how their utilization influences the economic welfare of the country. The research questions were answered with a help of theoretical model based on real life time-series observations.

The main value of this paper is the methodology presenting a set of methods and instruments that were implemented for the cost-benefit analysis of the biodiesel and bioethanol utilization in the Czech Republic. To the extent of the author's knowledge, there are no research papers published in English with the same methodology applied for the biofuels market of the Czech Republic.

The results of the research are contradictory. Theoretical framework reveled the trend of rapid growth in biofuels industry around the world, however, according to some researchers the market of the Czech Republic does not work for the full capacity. Despite the stated benefits of 1G biofuels utilization, there are significant shortcomings that challenge economic, social and environmental sustainability of 1G green fuels.

Czech Republic as well as other countries producing biofuels have several instruments to regulate this market. The main challenge of the biofuels policy in the Czech Republic is the significant subsidies that encourage the producers. Theoretical research showed that subsidies result in market inefficiencies and wrong allocation of the resources. This was proved by the model analysis. Estimations showed that Czech subsidized market of biodiesel and bioethanol has a shortcoming of deadweight loss (9.109 million CZK), which means that subsidies implementation in a short-run period result in overall net economic loss for the country. This research can be extended to the long run period analysis, which probably will confirm much bigger net loss.

The overall results of the model estimation are recommended to consider as preliminary background for further research. The quality of the model and estimations may be improved by the extension of the data set and introduction of additional variables that will allow removing the existing inconsistence in some of the calculations.

The research as well can be extended by the analysis of the environmental costs and benefits of biofuels utilization in the Czech Republic. This can be done by the monetization of GHG emissions based on EU emission trading system and data on the volume of GHG emissions changes associated with the Czech biofuel sector.

Furthermore, it would be interesting to analyze if there is a tight connection between biofuels expansion in the Czech Republic market and trends in the food prices. This question provokes wide debates around researchers and is discussed among EU authorities, therefore it may be important for the Czech Republic biofuels industry development.

The future of biofuels industry in the Czech Republic is unclear due to the uncertainty of oil price on the world market. Biofuels were proved to have a chance to compete with fossil fuels, however recent rapid decline of oil prices puts the challenge to the new level.

6 Bibliography

AFDC, 2016. EERE: Alternative Fuels Data Center Home Page. *Afdc.energy.gov* [online] [accessed. 12. January 2016]. Retrieved from: http://www.afdc.energy.gov/

Achten, W.M.J., A. Trabucco, W.H. Maes, L.V. Verchot, R. Aerts, E. Mathijs, P. Vantomme, V.P. Singh and B. Muys, 2013. Global greenhouse gas implications of land conversion to biofuel crop cultivation in arid and semi-arid lands – Lessons learned from Jatropha. *Journal of Arid Environments* [online]. vol. 98, pp. 135-145 [accessed. 10. November 2015]. Retrieved from: doi:10.1016/j.jaridenv.2012.06.015

Ajanovic, Amela, 2011. Biofuels versus food production: Does biofuels production increase food prices?. *Energy* [online]. vol. 36, no. 4, pp. 2070-2076 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.energy.2010.05.019

Ajanovic, A. and R. Haas, 2010. Economic challenges for the future relevance of biofuels in transport in EU countries. *Energy* [online]. vol. 35, no. 8, pp. 3340-3348. Retrieved from: doi:10.1016/j.energy.2010.04.020

Banse, Martin, Hans van Meijl, Andrzej Tabeau, Geert Woltjer, Fritz Hellmann and Peter H. Verburg, 2011. Impact of EU biofuel policies on world agricultural production and land use. *Biomass and Bioenergy* [online]. vol. 35, no. 6, pp. 2385-2390 [accessed. 1. February 2016]. Retrieved from: doi:10.1016/j.biombioe.2010.09.001

Barros, Sergio, 2014. *Biofuels Annual*: *Biofuels Annual. Brazil* [online]. B.m.: Globar Agricultural Informational Network [accessed. 12. January 2016]. Retrieved from: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Sao%20Paulo%20ATO_Brazil_7-25-2014.pdf

BBC, 2016. BBC - GCSE Bitesize: Fractional distillation. *Bbc.co.uk* [online] [accessed. 12. January 2016]. Retrieved from: http://www.bbc.co.uk/schools/gcsebitesize/science/aqa_pre_2011/rocks/fuelsrev3.shtml

Bell, David R., Thapat Silalertruksa, Shabbir H. Gheewala and Richard Kamens, 2011. The net cost of biofuels in Thailand—An economic analysis. *Energy Policy* [online]. vol. 39, no. 2, pp. 834-843 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.enpol.2010.11.002

BIOMASS Energy Center, 2016. What is BIOMASS?. *Biomassenergycentre.org.uk* [online] [accessed. 12. January 2016]. Retrieved from: http://www.biomassenergycentre.org.uk/portal/page?_pageid=76,15049&_dad=portal

Biofuels for Europe, 2016. Biofuels for Europe - Biofuels for Europe. *Biofuels for Europe* [online] [accessed. 19. December 2015]. Retrieved from: http://www.biofuelsforeurope.eu/

Bolognini, Silvia, 2015. The Future of Agro-Energy in the European Union Considering the Relationship between Food Emergency and Energy Emergency. *EFFL* [online]. vol. 10, no. 3, pp. 194-209 [accessed. 7. January 2016]. Retrieved from: http://eds.b.ebscohost.com.infozdroje.czu.cz/eds/detail/detail?vid=72&sid=c40acc91-

dfb3-431c-aa1c-742bff4dbdd7%40sessionmgr198&hid=108&bdata=JnNpdGU9ZWRzLWxpdmU%3d#db=a9h&AN=103296276

Boucher, P., R. Smith and K. Millar, 2014. Biofuels under the spotlight: The state of assessment and potential for integration. *Science and Public Policy* [online]. vol. 41, no. 3, pp. 283-293. Retrieved from: doi:10.1093/scipol/scu028

Bourguignon, Didier, 2015. *EU biofuels policy Dealing with indirect land use change* [online]. 1st ed. B.m.: EPRS | European Parliamentary Research Service [accessed. 20. December 2015]. Retrieved from: http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/548993/EPRS_BRI(2015)548993_REV1_EN.pdf

Brown, Richard P. C. and Harry F. Campbell, 2012. Consumer and Producer Surplus in Benefit-Cost Analysis. In: Richard P. C. Brown and Harry F. Campbell, ed. *Benefit-Cost Analysis* [online]. 1st ed. B.m.: Cambridge University Press, p. 146-176 [accessed. 2. December 2015]. Retrieved from: http://ebooks.cambridge.org/chapter.jsf?bid=CBO9780511791291&cid=CBO9780511791291A016

Burkart, Michael D and Stephen P Mayfield, 2013. Biofuels for the 21st Century. Current Opinion in Chemical Biology. no. 17, pp. 436-438.

Capros, Pantelis and Leonidas Mantzos, 2000. European Union post-Kyoto scenarios: benefits from accelerated technology progress. International Journal of Global Energy Issues [online]. vol. 14, number 1/2/3/4, p. 204. Retrieved from: doi:10.1504/ijgei.2000.004354

Chakrabortty, Aditya, 2008. Secret report: biofuel caused food crisis. *The Guardian* [online]. [accessed. 22. October 2015]. Retrieved from: http://www.theguardian.com/environment/2008/jul/03/biofuels.renewableenergy

Charemza, Wojciech and Derek Deadman, 1997. *New directions in econometric practice*. Lyme, N.H.: Edward Elgar Pub.

Chen, Xiaoguang, Haixiao Huang, Madhu Khanna and Hayri Onal, no date. Alternative Transportation Fuel Standards: Welfare Effects and Climate Benefits. *SSRN Electronic Journal* [online]. Retrieved from: doi:10.2139/ssrn.1907766

Ciaian, Pavel, Kancsz d'Artis and Miroslava Rajcaniova, 2013. *Bioenergy and global land use change* [online]. 1st ed. B.m.: The Open Access Publication Server of the ZBW – Leibniz Information Centre for Economics [accessed. 9. November 2015]. Retrieved from: https://www.econstor.eu/dspace/bitstream/10419/101046/1/766360598.pdf

Cobuloglu, Halil I. and İ. Esra Büyüktahtakın, 2015. Food vs. biofuel: An optimization approach to the spatio-temporal analysis of land-use competition and environmental impacts. *Applied Energy* [online]. vol. 140, pp. 418-434 [accessed. 13. January 2016]. Retrieved from: doi:10.1016/j.apenergy.2014.11.080

Cottrell, Allin and Riccardo Lucchetti, 2016. *Gretl*.

Czech Statistical Office, 2016. Statistics. *Czech Statistical Office* [online] [accessed. 12. January 2016]. Retrieved from: https://www.czso.cz/csu/czso/statistics

Čechura, Lukáš and Tomáš Maier, 2014. Econometric Modelling. In: Czech University of Life Sciences. Lecture.

de Almeida, and Bomtempo, 2007. *The PErformance of Brazilian Biofuels: an Economic, Environmental nad Social Analisys* [online]. B.m.: Federal University of Rio de Janeiro [accessed. 6. February 2016]. Retrieved from: http://www.internationaltransportforum.org/jtrc/discussionpapers /DiscussionPaper5.pdf

de Gorter, Harry and Dusan Drabik, 2011. Components of carbon leakage in the fuel market due to biofuel policies. *Biofuels* [online]. vol. 2, no. 2, pp. 119-121. Retrieved from: doi:10.4155/bfs.11.8

Demirbas, Ayhan, 2008. Biofuels sources, biofuel policy, biofuel economy and global biofuel projections. Energy Conversion and Management [online]. vol. 49, no. 8, pp. 2106-2116 [accessed. 12. January 2016]. Retrieved from: doi:10.1016 /j.enconman.2008.02.020

de Moraes, no date. *Reflections on Brazil's Ethanol Industry* [online]. 1st ed. B.m.: Agricultural College, University of São Paulo [accessed. 19. January 2016]. Retrieved from: http://dc.itamaraty.gov.br/imagens-e-textos/Biocombustiveis-08ing-consideracoesetanol.pdf

Dorward, Andrew, 2009. *RETHINKING AGRICULTURAL INPUT SUBSIDY PROGRAMMES IN A CHANGING WORLD* [online]. 1st ed. B.m.: Food and Agriculture Organization of the United Nations [accessed. 12. January 2016]. Retrieved from: https://www.oecd.org/tad/agricultural-policies/46384527.pdf

DREZE, JEAN and NICHOLAS STERN, 2016. THE THEORY OF COST-BENEFIT ANALYSIS. In: A.J. Auerbach and M. Feldstein, ed. *Handbook of Public Economics* [online]. 2nd ed. North-Holland: Elsevier Science Publishers B. V, p. 910-985 [accessed. 15. November 2015]. Retrieved from: http://personal.lse.ac.uk/sternn/040NHS.pdf

E15, 2015. Evropská komise schválila program podpory biopaliv [online]. [accessed. 12. January 2016]. Retrieved from: http://zpravy.e15.cz/zahranicni/politika/evropska-komise-schvalila-cesky-program-podpory-biopaliv-1217797

E85 Prices, 2016. E85 Prices. *E85prices.com* [online] [accessed. 12. January 2016]. Retrieved from: http://e85prices.com/

EIA, 2016. U.S. Energy Information Administration (EIA). *Eia.gov* [online] [accessed. 8. January 2016]. Retrieved from: http://www.eia.gov/

Elbehri, Aziz, Anna Segerstedt and Pascal Liu, 2013. *Biofuels and the sustainability challenge* [online]. Rome: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS [accessed. 10. January 2016]. Retrieved from: http://www.fao.org/3/a-i3126e.pdf

EPA, 2015. US Environmental Protection Agency. *Www3.epa.gov* [online] [accessed. 16. September 2015]. Retrieved from: https://www3.epa.gov/

Epple, Dennis and Bennett T. McCallum, 2005. *Simultaneous Equation Econometrics: The Missing Example* [online]. 1st ed. [accessed. 10. March 2016]. Retrieved from: https://www.uibk.ac.at/econometrics/dl/supply_demand.pdf

EUROPA, 2016. EUROPA - European Union website, the official EU website. *Europa.eu* [online] [accessed. 10. November 2015]. Retrieved from: http://europa.eu/

European Parliamentary Research Service, 2015. EU biofuels policy: Dealing with indirect land use change. *European Parliamentary Research Service Blog* [online] [accessed. 12. January 2016]. Retrieved from: http://epthinktank.eu/2015/01/23/eu-biofuels-policy-dealing-with-indirect-land-use-change/

EUROPEAN RENEWABLE ETHANOL, 2016. *Enabling Innovation and Sustainable Development. State of the industry 2015* [online]. Brussels: EUROPEAN RENEWABLE ETHANOL [accessed. 3. November 2016]. Retrieved from: http://epure.org/media/1215/epure_state_industry2015_web.pdf

Festel, Gunter, Martin Würmseher, Christian Rammer, Eckhard Boles and Martin Bellof, 2014. Modelling production cost scenarios for biofuels and fossil fuels in Europe. *Journal of Cleaner Production* [online]. vol. 66, pp. 242-253 [accessed. 11. January 2016]. Retrieved from: doi:10.1016/j.jclepro.2013.10.038

Feuillette, Sarah, Harold Levrel, Blandine Boeuf, Stéphanie Blanquart, Olivier Gorin, Guillaume Monaco, Bruno Penisson and Stéphane Robichon, 2016. The use of cost–benefit analysis in environmental policies: Some issues raised by the Water Framework Directive implementation in France. *Environmental Science & Policy* [online]. vol. 57, pp. 79-85 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.envsci.2015.12.002

Flach, Bob, Karin Bendz and Sabine Lieberz, 2014. *Biofuels Annual*: *EU Biofuels Annual 2014* [online]. B.m.: Global Agricultural Informational Network [accessed. 19. January 2016]. Retrieved from: http://gain.fas.usda.gov/Recent%20GAIN%20Publications /Biofuels%20Annual_The%20Hague_EU-28_7-3-2014.pdf

Food and Agriculture Organization of the United Nations, 2008. *THE STATE OF FOOD AND AGRICULTURE*: *BIOFUELS: prospects, risks and opportunities* [online]. Rome: Food and Agriculture Organization of the United Nations [accessed. 12. December 2015]. Retrieved from: http://ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e.pdf

Gao, Jinglei, Zengwei Yuan, Xuewei Liu, Xiaoming Xia, Xianjin Huang and Zhanfeng Dong, 2016. Improving air pollution control policy in China—A perspective based on cost–benefit analysis. *Science of The Total Environment* [online]. vol. 543, no. Part A, pp. 307-314 [accessed. 15. November 2015]. Retrieved from: doi:10.1016 /j.scitotenv.2015.11.037

GNS Science, 2016. Home - GNS Science. *Gns.cri.nz* [online] [accessed. 16. December 2015]. Retrieved from: http://www.gns.cri.nz/

GOLDEMBERG, JOSÉ, 2016. Sweetening the Biofuel Sector: The History of Sugarcane Ethanol in Brazil | Bioenergy Connection. *Bioenergyconnection.org* [online] [accessed. 15. December 2015]. Retrieved from: http://bioenergyconnection.org/article/sweetening-biofuel-sector-history-sugarcane-ethanol-brazil

GRANGER, C.W.J. and P. NEWBOLD, 1973. *SPURIOUS REGRESSIONS IN ECONOMETRICS* [online]. 1st ed. Nottingham: Journal of Econometrics [accessed. 10. March 2016]. Retrieved from: http://wolfweb.unr.edu/homepage/zal/STAT758 /Granger_Newbold_1974.pdf

G. SPEIGHT, James and Ljiljana RADOVANOVIĆ, 2015. BIOFUELS: FUTURE BENEFITS AND RISKS. *ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering* [online]. no. VIII [accessed. 12. November 2015]. Retrieved from: http:// eds.b.ebscohost.com.infozdroje.czu.cz/eds/pdfviewer/pdfviewer?sid=7160feec-3717-4ce7-8909-74c93de8ae3d@sessionmgr102&vid=2&hid=111&preview=false

Guo, Mingxin, Weiping Song and Jeremy Buhain, 2015. Bioenergy and biofuels: History, status, and perspective. *Renewable and Sustainable Energy Reviews* [online]. vol. 42, pp. 712-725 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.rser.2014.10.013

Hamelinck, Carlo, 2013. *Biofuels and food security Risks and opportunities* [online]. 1st ed. B.m.: Ecofys [accessed. 12. November 2015]. Retrieved from: http://www.ecofys.com /files/files /ecofys-2013-biofuels-and-food-security.pdf

Havlík, Petr, Uwe A. Schneider, Erwin Schmid, Hannes Böttcher, Steffen Fritz, Rastislav Skalský, Kentaro Aoki, Stéphane De Cara, Georg Kindermann, Florian Kraxner, Sylvain Leduc, Ian McCallum, Aline Mosnier, Timm Sauer and Michael Obersteiner, 2011. Global land-use implications of first and second generation biofuel targets. *Energy Policy* [online]. vol. 39, no. 10, pp. 5690-5702 [accessed. 10. November 2015]. Retrieved from: doi:10.1016/j.enpol.2010.03.030

High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, 2013. *Biofuels and food security* [online]. Rome: HLPE [accessed. 19. October 2015]. Retrieved from: http://www.fao.org/fileadmin/user_upload /hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-5_Biofuels_and_food_security.pdf

Ho, Dang P., Huu Hao Ngo and Wenshan Guo, 2014. A mini review on renewable sources for biofuel. *Bioresource Technology* [online]. vol. 169, pp. 742-749 [accessed. 23. September 2015]. Retrieved from: doi:10.1016/j.biortech.2014.07.022

Holland, Paula, 2012. *SPC SOPAC Division*: *Simple Introduction to Cost-Benefit Analysis* [online]. B.m.: Technical Support Services, Natural Resources Governance Unit [accessed. 5. November 2015]. Retrieved from: http://www.sopac.org/dsm/public/ files/reports/PR008444.pdf

Huenteler, Joern, Laura Diaz Anadon, Henry Lee and Nidhi Santen, 2014. *Commercializing Second-Generation Biofuels Scaling Up Sustainable Supply Chains and the Role of Public Policy* [online]. Cambridge: President and Fellows of Harvard College [accessed. 17. December 2015]. Retrieved from: http://belfercenter.ksg.harvard.edu/files /commercializing-2ndgen-biofuels-web-final.pdf

iDnes.cz Ekonomika, 2015. Vláda schválila návrh na další daňovou podporu biopaliv. *iDnes.cz* [online]. [accessed. 27. February 2016]. Retrieved from: http://ekonomika.idnes.cz/ vlada-schvalila-navrh-na-dalsi-danovou-podporu-biopaliv-pjs-/ekonomika.aspx?c=A150223_145205_ekonomika_kop

International Energy Agency, 2014. *Energy Supply Security 2014*: *Emergency response systems of individual IEA countries. Czech Republic* [online]. B.m.: International Energy Agency [accessed. 19. December 2015]. Retrieved from: https://www.iea.org /media/freepublications/security/EnergySupplySecurity2014_TheCzechRepublic.pdf

Investopedia, 2016. Investopedia - Educating the world about finance. *Investopedia* [online] [accessed. 12. January 2016]. Retrieved from: http://www.investopedia.com

James, Lawrence R. and B. Krishna Singh, 1978. An introduction to the logic, assumptions, and basic analytic procedures of two-stage least squares. *Psychological Bulletin* [online]. vol. 85, no. 5, pp. 1104-1122. Retrieved from: doi:10.1037/0033-2909.85.5.1104

Jehlickova, Bohumira and Richard Morris, 2007. Effectiveness of policy instruments for supporting the use of waste wood as a renewable energy resource in the Czech Republic. *Energy Policy* [online]. vol. 35, no. 1, pp. 577-585 [accessed. 6. January 2016]. Retrieved from: doi:10.1016/j.enpol.2005.12.024

Johnson, Julia, no date. Promoting the Sustainability of Biofuels in America: Looking to Brazil. *SSRN Electronic Journal* [online]. Retrieved from: doi:10.2139/ssrn.2499310

Jurčík, Radek, 2015. *Subsidies for Biofuels and Current Development in 2015* [online]. 1st ed. B.m.: LISTY CUKROVARNICKÉ a ŘEPAŘSKÉ [accessed. 12. January 2016]. Retrieved from: http://www.cukr-listy.cz/on_line/2015/PDF/355-358.pdf

KOLB, RON, 2016. A Short History of Biofuels | Bioenergy Connection. *Bioenergyconnection.org* [online] [accessed. 15. December 2015]. Retrieved from: http://bioenergyconnection.org/article/short-history-biofuels

Koplow, Doug and Ronald Steenblik, 2008. ubsidies to Ethanol in the United States. In: D. Pimentel, ed. *Biofuels, Solar and Wind as Renewable Energy Systems* [online]. 1st ed. B.m.: Springer Science+Business Media B.V, p. 82-104 [accessed. 17. January 2016]. Retrieved from: https://earthtrack.net/sites/default/files/ Biofuels2008_Pimentel%20Chapter.pdf

Kurzy.cz, 2016. Kurzy ČNB. *Kurzy.cz* [online] [accessed. 12. January 2016]. Retrieved from: http://www.kurzy.cz/kurzy-men/kurzy.asp?A=H&rok_source=1&interval_typ=1&rok=2010

Kurzy.cz, 2016. Gasoline RBOB - aktuální a historické ceny. *Kurzy.cz* [online] [accessed. 12. January 2016]. Retrieved from: http://www.kurzy.cz/komodity/index.asp?A=5&idk=93&od=29.9.2003&do=16.3.2016&curr=CZK

Kurzy.cz, 2016. Motorová nafta - aktuální a historické ceny. *Kurzy.cz* [online] [accessed. 12. January 2016]. Retrieved from: http://www.kurzy.cz/komodity/index.asp?A=5&idk=39&od=01.1.2010&do=1.1.2015&curr=CZK

Kurzy.cz, 2016. Řepka jarní. *Kurzy.cz* [online] [accessed. 12. January 2016]. Retrieved from: http://www.kurzy.cz/komodity/index.asp?A=5&idk=9&od=01.12.2004&do=31.12.2014&curr=CZK&MAXROWS=60

Kyoto Protcol, 2015. KyotoProtocol - Toward Climate Stability. Kyotoprotocol.com [online] [accessed. 16. November 2015]. Retrieved from: http://www.kyotoprotocol.com/

Leite, Gustavo B., Ahmed E.M. Abdelaziz and Patrick C. Hallenbeck, 2013. Algal biofuels: Challenges and opportunities. Bioresource Technology [online]. vol. 145, pp. 134-141 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.biortech.2013.02.007

Lewandowski, I., J. Weger, A. van Hooijdonk, K. Havlickova, J. van Dam and A. Faaij, 2006. The potential biomass for energy production in the Czech Republic. *Biomass and Bioenergy* [online]. vol. 30, no. 5, pp. 405-421 [accessed. 14. December 2015]. Retrieved from: doi:10.1016/j.biombioe.2005.11.020

Lin, C.-Y. Cynthia, 2011. *Estimating Supply and Demand in the World Oil Market* [online]. 1st ed. B.m.: THE JOURNAL OF ENERGY AND DEVELOPMENT [accessed. 12. January 2016]. Retrieved from: http://www.des.ucdavis.edu/faculty/Lin/oil_mkt_sd_paper.pdf

Lin, Yan and Shuzo Tanaka, 2005. Ethanol fermentation from biomass resources: current state and prospects. *APPLIED MICROBIOLOGY AND BIOTECHNOLOGY* [online]. vol. 69, no. 6, pp. 627-642 [accessed. 12. January 2016]. Retrieved from: doi:10.1007/s00253-005-0229-x

Linares, Pedro and Ignacio J. Pérez-Arriaga, 2013. A sustainable framework for biofuels in Europe. *Energy Policy* [online]. vol. 52, pp. 166-169. Retrieved from: doi:10.1016/j.enpol.2012.10.008

Lu, Hongfang, Bin-Le Lin, Daniel E. Campbell, Masayuki Sagisaka and Hai Ren, 2012. Biofuel vs. biodiversity? Integrated emergy and economic cost-benefit evaluation of rice-ethanol production in Japan. *Energy* [online]. vol. 46, no. 1, pp. 442-450 [accessed. 11. January 2016]. Retrieved from: doi:10.1016/j.energy.2012.08.005

Maddala, G.S., 1992. *Introduction to econometrics* [online]. 2nd ed. New York: Macmillan Publishing Company [accessed. 12. January 2016]. Retrieved from: https://jigjids.files.wordpress.com/2011/05/introduction-to-econometric-2nd.pdf

Majerus, Gerard A., 1982. *Econometric estimation of demand and supply curves for timber in Montana, 1962-1980*. The University of Montana.

Massiani, Jérôme, 2015. Cost-Benefit Analysis of policies for the development of electric vehicles in Germany: Methods and results. *Transport Policy* [online]. vol. 38, pp. 19-26 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.tranpol.2014.10.005

Mikulasova, Jana, 2015. *Biofuels Annual 2015*: *Biofuels Annual 2015. Czech Republic* [online]. B.m.: Global Agricultural Informational Network [accessed. 28. January 2016]. Retrieved from: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual%202015_Prague_Czech%20Republic_7-29-2015.pdf

Miller, Ian, 2014. *Biofuels. An Overview*. B.m.: Smashwords Edition.

Ministerstvo zemědělství, 2015. *SITUAČNÍ A VÝHLEDOVÁ ZPRÁVA CUKR – CUKROVÁ ŘEPA* [online]. 1st ed. Prague: Ministerstvo zemědělství [accessed. 12. January 2016]. Retrieved from: http://eagri.cz/public/web/file/424652/CUKR_06_2015.PDF

Ministerstvo zemědělství, 2014. *VÍCELETÝ PROGRAM PODPORY DALŠÍHO UPLATNĚNÍ UDRŽITELNÝCH BIOPALIV V DOPRAVĚ NA OBDOBÍ 2015 - 2020* [online]. 1st ed. Prague: Ministerstvo zemědělství [accessed. 12. January 2016]. Retrieved from: http://eagri.cz/public/web/file/327185/Vicelety_program_2014.pdf

Ministry of Industry and Trade, 2010. *National Renewable Energy Action Plan of the Czech Republic* [online]. B.m.: Ministry of Industry and Trade [accessed. 28. January 2016]. Retrieved from: http://www.ebb-eu.org/legis/ActionPlanDirective2009_28/national_renewable_energy_action_plan_czechrepublic_en.pdf

Miron, Jefrey A., 2009. Consumer Surplus. In: Harvard Business School. Lecture.

Møller, Flemming, Erik Slentø and Pia Frederiksen, 2014. Integrated well-to-wheel assessment of biofuels combining energy and emission LCA and welfare economic Cost Benefit Analysis. *Biomass and Bioenergy* [online]. vol. 60, pp. 41-49 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.biombioe.2013.11.001

Numbeo.com, 2016. Pollution Index for Country. *Numbeo.com* [online] [accessed. 12. January 2016]. Retrieved from: http://www.numbeo.com/pollution/rankings_by_country.jsp

OECD, 2016. OECD.org - OECD. *Oecd.org* [online] [accessed. 12. January 2016]. Retrieved from: http://www.oecd.org/

OECD/Food and Agriculture Organization of the United Nations, 2015. *Agricultural Outlook 2015-2024* [online]. Paris: OECD Publishing [accessed. 12. January 2016]. Retrieved from: http://www.fao.org/3/a-i4738e.pdf

Organisation for Economic Co-operation and Development, 2016. Agricultural policies and support - OECD. Oecd.org [online] [accessed. 12. January 2016]. Retrieved from: http://www.oecd.org/tad/agricultural-policies/

Panichelli, Luis and Edgard Gnansounou, 2015. Impact of agricultural-based biofuel production on greenhouse gas emissions from land-use change: Key modelling choices.

Renewable and Sustainable Energy Reviews [online]. vol. 42, pp. 344-360 [accessed. 1. March 2016]. Retrieved from: doi:10.1016/j.rser.2014.10.026

Piroli, Giuseppe, Miroslava Rajcaniova, Pavel Ciaian and dʹArtis Kancs, 2015. From a rise in B to a fall in C? SVAR analysis of environmental impact of biofuels. *Renewable and Sustainable Energy Reviews* [online]. vol. 49, pp. 921-930 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.rser.2015.04.133

Poonyth, Daneswar, Alexander Sarris, Shangnan Shui and Ramesh Sharma, 2004. The Impact of Domestic and Trade Policies on The World Cotton Market. *Fao.org* [online] [accessed. 12. January 2016]. Retrieved from: http://www.fao.org/docrep/007 /j2731e/j2731e00.htm#Contents

Puget Sound Regional Council, 2010. *Benefit-Cost Analysis: General Methods and Approach* [online]. Seattle: Puget Sound Regional Council [accessed. 16. November 2015]. Retrieved from: http://www.psrc.org/assets/2127/BCA_ Methods_Report_Mar2010update.pdf?processed=true

Raboni, Massimo, Paolo Viotti and Andrea G. Capodaglio, 2015. A comprehensive analysis of the current and future role of biofuels for transport in the European Union (EU). *Rev. ambiente água* [online]. vol. 10, no. 1 [accessed. 8. March 2016]. Retrieved from: doi:10.4136/ambi-agua.1492

Rapsomanikis, George, 2014. *Nonlinear cointegration in the food-ethanol-oil system Evidence from smooth threshold vector error correction models* [online]. 1st ed. B.m.: Agricultural Development Economics Division Food and Agriculture Organization of the United Nations [accessed. 12. January 2016]. Retrieved from: http://www.fao.org/3/a-i3697e.pdf

Renewable Energy Policy Network for the 21st Century (REN21), 2016. *RENEWABLES*: *RENEWABLES 2015 GLOBAL STATUS REPORT* [online]. Paris: REN21 [accessed. 12. January 2016]. Retrieved from: http://www.ren21.net/wp-content/uploads/ 2015/07/REN12-GSR2015_Onlinebook_low1.pdf

Santamaría, Marta and Diego Azqueta, 2015. Promoting biofuels use in Spain: A cost-benefit analysis. *Renewable and Sustainable Energy Reviews* [online]. vol. 50, pp. 1415-1424 [accessed. 1. March 2016]. Retrieved from: doi:10.1016/j.rser.2015.04.192

Sexton, Steven, Deepak Rajagopal, David Zilberman and Gal Hochman, 2008. Food Versus Fuel: How Biofuels Make Food More Costly and Gasoline Cheaper. *Agricultural and Resource Economics Update* [online]. vol. 1, no. 12, pp. 1-6 [accessed. 23. September 2015]. Retrieved from: http://giannini.ucop.edu/media/are-update/files/ articles/v12n1_1.pdf

Sheridan, Cormac, 2013. Big oil turns on biofuels. *Nat Biotechnol* [online]. vol. 31, no. 10, pp. 870-873. Retrieved from: doi:10.1038/nbt.2704

Sims, Brayan, 2011. *Biodiesel Magazine* [online]. no. EU member states increase biofuel blending quotas [accessed. 10. October 2015]. Retrieved from:

http://biodieselmagazine.com/articles/8007/eu-member-states-increase-biofuel-lending-quotas

Sims, Ralph, Michael Taylor, Jack Saddler and Warren Mabee, 2016. *From 1st to 2nd Generation Biofuel Technologies* [online]. 1st ed. Paris: Economic Co-operation and Development and International Energy Agency [accessed. 12. December 2015]. Retrieved from: https://www.iea.org/publications/freepublications/publication/2nd_Biofuel_Gen.pdf

Sinn, Hans-Werner, 2008. Public policies against global warming: a supply side approach. *International Tax and Public Finance* [online]. vol. 15, no. 4, pp. 360-394 [accessed. 12. January 2016]. Retrieved from: doi:10.1007/s10797-008-9082-z

Sorda, Giovanni, Martin Banse and Claudia Kemfert, 2010. An overview of biofuel policies across the world. *Energy Policy* [online]. vol. 38, no. 11, pp. 6977-6988. Retrieved from: doi:10.1016/j.enpol.2010.06.066

SPEIGHT, James G. and Ljiljana RADOVANOVIĆ, 2015. *BIOFUELS: FUTURE BENEFITS AND RISKS* [online]. 1st ed. B.m.: Acta Technica Corvininesis - Bulletin Of Engineering, [accessed. 15. September 2015]. Retrieved from: http://eds.b.ebscohost.com. infozdroje.czu.cz/eds/pdfviewer/pdfviewer?sid=b8426de6-fe3f-4d7a-b0cd-2f5c8cf31c8f@sessionmgr120&vid=2&hid=111&preview=false

Statista.com., 2016. World carbon dioxide emissions by region 2014. *Statista* [online] [accessed. 12. January 2016]. Retrieved from: http://www.statista.com/statistics/205966/world-carbon-dioxide-emissions-by-region/

Stephen, James D., Warren E. Mabee and Jack N. Saddler, 2011. Will second-generation ethanol be able to compete with first-generation ethanol? Opportunities for cost reduction. *Biofuels, Bioprod. Bioref.* [online]. vol. 6, no. 2, pp. 159-176. Retrieved from: doi:10.1002/bbb.331

Stattman, Sarah L., Otto Hospes and Arthur P.J. Mol, 2013. Governing biofuels in Brazil: A comparison of ethanol and biodiesel policies. *Energy Policy* [online]. vol. 61, pp. 22-30 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.enpol.2013.06.005

Šauer, Petr, Jaroslav Kreuz, Antonín Dvořák and Alena Hadrabová, 2012. Assessment of Environmental Policy Implementation: Two Case Studies from the Czech Republic. *Pol. J. Environ. Stud.*. vol. 21, no. 5, pp. 1383-1391.

Tamers, Murry, 2006. Distinguishing Between Bio-Ethanol' and Petroleum Ethanol. *Ethanol Producer Magazine* [online]. [accessed. 12. January 2016]. Retrieved from: http://www.ethanolproducer.com/articles/2077/distinguishing-between-%91bio-ethanol'-and-petroleum-ethanol/

The Calculator Site, 2016. Convert Liters To Metric Tons - The Calculator Site. *Thecalculatorsite.com* [online] [accessed. 12. January 2016]. Retrieved from: http://www.thecalculatorsite.com/conversions/common/liters-to-metric-tons.php

Thengane, Sonal K., Andrew Hoadley, Sankar Bhattacharya, Sagar Mitra and Santanu Bandyopadhyay, 2014. Cost-benefit analysis of different hydrogen production technologies using AHP and Fuzzy AHP. *International Journal of Hydrogen Energy* [online]. vol. 39, no. 28, pp. 15293-15306 [accessed. 14. January 2016]. Retrieved from: doi:10.1016/j.ijhydene.2014.07.107

Tol, Richard S.J., 2012. A cost–benefit analysis of the EU 20/20/2020 package. *Energy Policy* [online]. vol. 49, pp. 288-295 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.enpol.2012.06.018

Tradingeconomics, 2016. Czech Republic Average Monthly Wages | 1994-2016 | Data | Chart | Calendar. *Tradingeconomics.com* [online] [accessed. 12. January 2016]. Retrieved from: http://www.tradingeconomics.com/czech-republic/wages

Van Noorden, Richard, 2013. EU debates U-turn on biofuels policy. *Nature* [online]. vol. 499, no. 7456, pp. 13-14. Retrieved from: doi:10.1038/499013a

van Thuijl, E. and E.P. Deurwaarder, 2006. *European biofuel policies in retrospect* [online]. 1st ed. B.m.: Energy Research Center of the Netherlands [accessed. 14. October 2015]. Retrieved from: https://www.ecn.nl/docs/library/report/2006/c06016.pdf

V, Sameera, 2011. Current Strategies Involved in Biofuel Production from Plants and Algae. *J Microbial Biochem Technol* [online]. vol. R1, no. 01 [accessed. 19. December 2015]. Retrieved from: doi:10.4172/1948-5948.r1-002

van Eijck, Janske, Bothwell Batidzirai and André Faaij, 2014. Current and future economic performance of first and second generation biofuels in developing countries. *Applied Energy* [online]. vol. 135, pp. 115-141 [accessed. 12. January 2016]. Retrieved from: doi:10.1016/j.apenergy.2014.08.015

von Braun, Joachim, 2008. Biofuels, International Food Prices, and the Poor Joachim von Braun. *International Food Policy Research Institute (IFPRI)* [online]. [accessed. 12. January 2016]. Retrieved from: http://cdm15738.contentdm.oclc.org/u?/p15738coll2,10408

Wooldridge, Jeffrey M., 2009. *Introductory Econometrics* [online]. 4th ed. Mason: South-Western, a part of Cengage Learning [accessed. 14. January 2016]. Retrieved from: http://ncbae.yolasite.com/resources/IntroductoryEconometrics_AModernApproach_FourthEdition_Jeffrey_Wooldridge.pdf

Wiesenthal, Tobias, Guillaume Leduc, Panayotis Christidis, Burkhard Schade, Luc Pelkmans, Leen Govaerts and Panagiotis Georgopoulos, 2009. Biofuel support policies in Europe: Lessons learnt for the long way ahead. *Renewable and Sustainable Energy Reviews* [online]. vol. 13, no. 4, pp. 789-800. Retrieved from: doi:10.1016/j.rser.2008.01.011

WTO, 2016. World Trade Organization - Home page. *Wto.org* [online] [accessed. 20. November 2015]. Retrieved from: https://www.wto.org

Yue, Dajun, Fengqi You and Seth W. Snyder, 2014. Biomass-to-bioenergy and biofuel supply chain optimization: Overview, key issues and challenges. *Computers & Chemical Engineering* [online]. vol. 66, pp. 36-56 [accessed. 20. November 2015]. Retrieved from: doi:10.1016/j.compchemeng.2013.11.016

7 Appendix

Appendix 1 Basic data set.

Date	Total biodiesel and bioethanol production, tons	Total biodiesel and bioethanol consumption, tons	Rapeseed price, CZK/ton	Sugarbeet price, CZK/ton	Subsidies, mil. CZK	Average salary, CZK	Bioethanol price, CZK/ton	Biodiesel price, CZK/ton	Dioesel price, CZK/ton	Gasoline price, CZK/ton	Blending obligations, %
01.01.2010	24229	13762	6751,738	720,9533	42,43327	23682,1	13613,83	25081,57	11394,21	13977,6	9,30
01.02.2010	17108	15061	7081,511	721,67	53,35241	23859,2	12926,11	25134,90	11531,92	14229,6	9,30
01.03.2010	24681	16284	7217,478	720,9533	53,41742	23573,1	12628,44	24826,22	12356,20	15822,8	9,30
01.04.2010	23956	18583	7277,943	718,1009	57,58823	22339,7	11948,98	25830,15	13381,96	16331,9	9,30
01.05.2010	25992	16999	7466,403	717,3913	49,07785	23981,3	12748,90	27907,96	13188,45	15997,8	9,30
01.06.2010	26259	20505	7698,617	717,3913	68,38648	24315,9	12768,34	28896,10	13632,65	16370,9	9,30
01.07.2010	23037	24163	7408,243	712,4632	57,36171	23681,6	11679,28	24057,20	12701,06	15149	9,30
01.08.2010	20775	21150	7528,95	712,4632	63,42012	24320,7	14446,32	27071,36	12479,97	14208	9,30
01.09.2010	26519	24117	7623,529	711,7647	65,39592	22482,4	14228,07	25112,04	12369,9	13576,1	9,30
01.10.2010	28136	28104	8289,216	659,8039	67,4229	22240,5	12030,98	22507,00	12441,5	13767,5	9,30
01.11.2010	27937	26466	8461,765	678,4314	67,43786	24202,6	16220,56	27254,90	13026,8	14624,5	9,30
01.12.2010	23255	28034	8570,87	704,7898	67,2451	23504,4	16040,71	26951,54	14156,8	16541	9,30
01.01.2011	22740	28255	10140,61	701,0816	86,82077	24290,6	15680,91	26169,41	14640,4	16617,5	10,10
01.02.2011	20845	25477	11620,83	700,3929	84,28957	24228,3	16955,44	27659,28	14620,4	16875,5	10,10
01.03.2011	24737	27501	11632,25	701,0816	81,91428	23811,6	16468,77	27377,44	16573,2	19394,5	10,10

Source: Czech Statistical Office, Kurzy.cz, Ministry of Industry and trade, own computation

Appendix 1 Basic data set (cont)

Date	Total biodiesel and bioethanol production, tons	Total biodiesel and bioethanol consumption, tons	Rapeseed price, CZK/ton	Sugarbeet price, CZK/ton	Subsidies, mil. CZK	Average salary, CZK	Bioethanol price, CZK/ton	Biodiesel price, CZK/ton	Dioesel price, CZK/ton	Gasoline price, CZK/ton	Blending obligations, %
01.04.2011	24279	30331	11510,83	701,7717	86,82959	23445,2	16032,01	25224,97	16935,7	20402,9	10,10
01.05.2011	23250	28924	11719,61	699,0196	91,29665	24464,6	17363,50	26596,64	15832,8	19448,7	10,10
01.06.2011	15833	28532	11561,89	700,3929	86,56577	24114,7	17178,05	25694,64	15663,9	18489	10,10
01.07.2011	14792	25260	10665,68	701,0816	94,71426	23306,6	16948,75	27138,64	16112,4	19669,4	10,10
01.08.2011	18110	26153	10630,29	701,0816	97,55961	23270,6	18743,79	28641,66	15445,8	18035,6	10,10
01.09.2011	22634	25113	10745,58	700,3929	79,96096	25560,7	15922,00	28164,47	16069	18048,6	10,10
01.10.2011	26863	25696	10648,09	702,8348	93,95759	22705,8	19277,32	31322,44	16352,3	17966,1	10,10
01.11.2011	24976	25469	10563,9	849,7561	93,70117	23756,2	20519,42	33128,92	17558,3	17855	10,10
01.12.2011	25449	27467	10516,6	817,3828	90,82926	24969,9	16376,06	30287,39	17372,8	18566,6	10,10
01.01.2012	26233	25153	10629,95	733,3333	104,5592	25091,9	16033,86	29661,84	18318,4	20197,2	10,10
01.02.2012	24021	26232	10698,17	704,918	108,6994	24177,5	15243,18	28530,10	18222,6	20767,7	10,10
01.03.2012	25385	29342	11002,89	704,2389	108,4823	24019,2	15630,34	29121,94	18480	22717,9	10,10
01.04.2012	25371	30892	11193,24	706,2802	117,6188	22795,1	15608,21	31028,30	18246,4	22390,6	10,10
01.05.2012	26302	31330	11742,25	708,3333	99,94384	25249,1	16292,47	33887,04	17722,8	21291,5	10,10
01.06.2012	22545	30067	11800	706,2802	139,7462	24373,5	16479,90	34092,48	16561,7	19793,7	10,10
01.07.2012	15350	27840	11834,14	709,0204	98,63631	24795,1	19677,56	35845,92	17904,3	21407,8	10,10
01.08.2012	18404	30246	11428,85	707,6476	108,6389	23770,6	18284,78	33314,89	18835,7	22322,4	10,10
01.09.2012	20165	25522	11588,97	706,9632	111,8841	23483,3	16760,62	30823,43	18291,2	20918,8	10,10
01.10.2012	24662	32503	11637,33	802,7079	115,2462	24451,8	17679,31	31638,57	18054,2	19720	10,10
01.11.2012	21684	21842	11881,21	821,8111	115,9848	24725,2	17158,89	31450,83	18050,5	19533,6	10,10

Source: Czech Statistical Office, Kurzy.cz, Ministry of Industry and trade, own computation

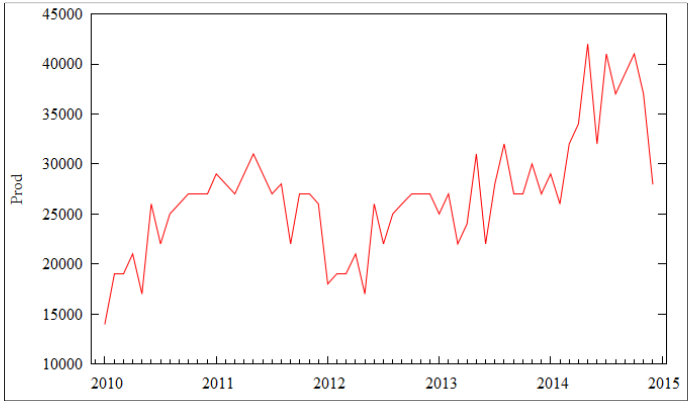
Appendix 1 Basic data set (cont)

Date	Total biodiesel and bioethanol production, tons	Total biodiesel and bioethanol consumption, tons	Rapeseed price, CZK/ton	Sugarbeet price, CZK/ton	Subsidies, mil. CZK	Average salary, CZK	Bioethanol price, CZK/ton	Biodiesel price, CZK/ton	Dioesel price, CZK/ton	Gasoline price, CZK/ton	Blending obligations, %
01.12.2012	24813	20889	12163,09	787,1094	116,2923	24244,8	16404,76	30622,21	17418	19068,5	10,10
01.01.2013	21359	26215	11731,11	764,475	120,5957	23917,5	17300,94	31263,14	18020,7	20119,7	10,50
01.02.2013	19460	24293	11975,42	687,3156	128,4697	24919,3	17951,81	32293,86	18549	21566,2	10,50
01.03.2013	21416	18809	12114,06	687,3156	109,403	25455	17042,68	31507,23	17860,2	22920,6	10,50
01.04.2013	18123	20865	12000	687,3156	117,0824	24579,2	18985,77	32841,69	16893,1	20813,5	10,50
01.05.2013	29207	31332	11854,89	690,0296	144,4418	24940,9	18015,90	32054,72	17012,3	21106,6	10,50
01.06.2013	18503	25138	11437,99	687,9921	109,7132	25094,6	16452,62	30638,36	16768,6	20401,4	10,50
01.07.2013	20940	26509	10504,93	689,3491	128,0238	25030,4	18960,27	31262,33	17829,8	22170,8	10,50
01.08.2013	21438	29822	10156,96	690,0296	142,8681	25021,1	12546,80	25708,64	17912,1	21430,5	10,50
01.09.2013	23765	29972	9623,762	692,0792	125,2132	24460,7	17390,01	29222,07	17910,4	19767	10,50
01.10.2013	31521	26894	9237,859	787,9088	125,547	23658,5	16198,59	28953,70	17286,7	18543,5	10,50
01.11.2013	29418	28810	9369,931	821,9585	136,4821	25049,5	12774,11	26974,71	18037,7	19604,8	10,50
01.12.2013	31034	25408	9508,876	843,1953	125,4323	24666	17557,55	31234,15	18547	20270,4	10,50
01.01.2014	28160	30867	9690,619	820,3593	160,9021	26460,9	13959,23	24351,30	18342,7	20141,5	10,50
01.02.2014	26090	27875	9848,303	860,2794	148,0957	25667,4	16585,26	25306,53	18460,1	20899,6	10,50
01.03.2014	25686	27585	10056,89	860,2794	174,9319	25849,6	30429,88	31308,81	17817,5	21865,8	10,50
01.04.2014	28270	32263	10386,61	861,1389	184,3862	25555,1	18150,63	30069,93	18001,7	22523,9	10,50
01.05.2014	27920	40351	11002,99	858,5657	219,475	25940,7	17030,85	29439,39	18063,7	22299,4	10,50
01.06.2014	20152	37655	10880	862	176,8017	25899,8	16874,86	31614,29	18451,1	23245	10,50
01.07.2014	22878	38008	9200,995	857,7114	203,9917	24834,6	17468,06	36318,41	17951,3	22196,5	10,50
01.08.2014	24129	38215	9277,336	856,8588	188,0399	25355	17994,32	37219,54	18092,4	21429,2	10,50
01.09.2014	21334	34807	9061,569	863,9523	196,675	26108,2	13712,28	33862,96	17727,9	20788,2	10,50
01.10.2014	34954	42963	8974,181	802,3833	205,5312	24782,3	16883,64	34458,79	16342,7	18395,3	10,50
01.11.2014	33753	38877	8906,561	822,0676	190,0894	24830,4	21682,72	39193,41	15565,1	17064,5	10,50
01.12.2014	30102	29989	8951,049	816,1838	154,791	25687	17674,35	34308,55	12899,2	13751,2	10,50

Source: Czech Statistical Office, Kurzy.cz, Ministry of Industry and trade, own computation

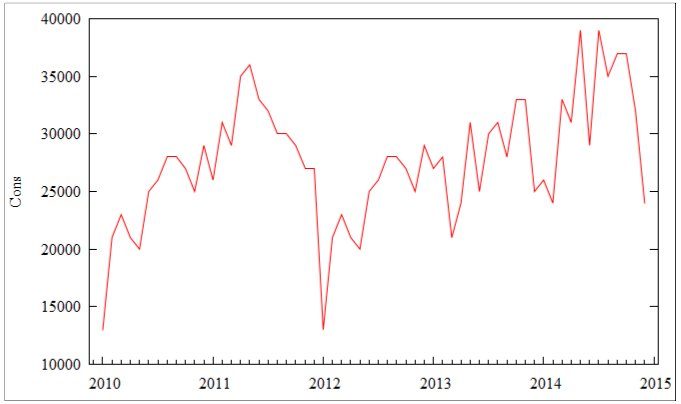
Appendix 2

Figure 1 Time-series plot for "Prod" variable



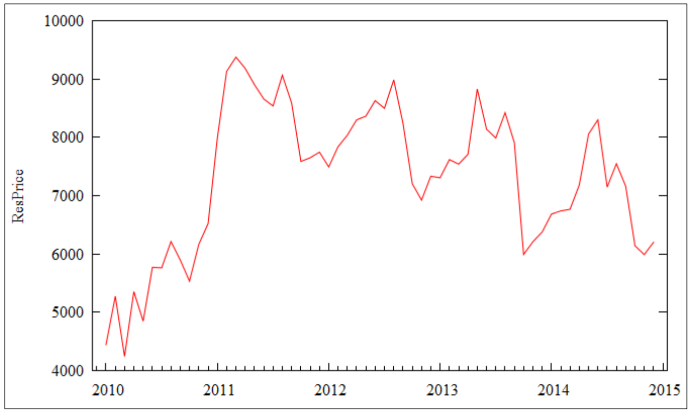
Source: Gretl Software

Figure 2 Time-series plot for "Cons" variable



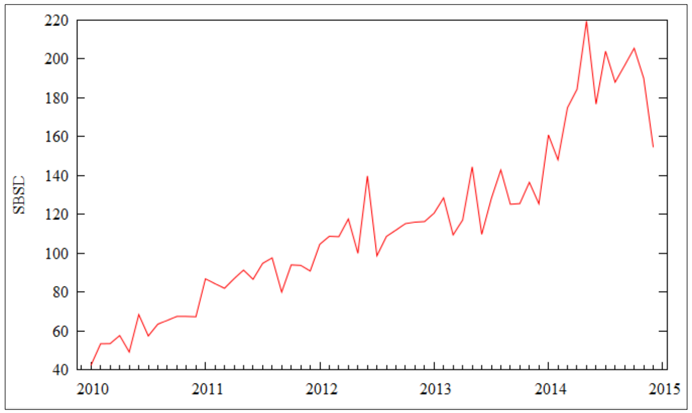
Source: Gretl Software

Figure 3 Time-series plot for "ResPrice" Variable



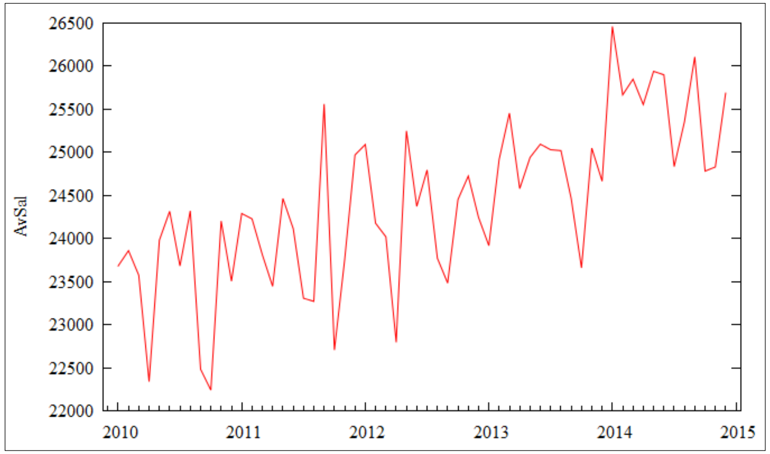
Source: Gretl Software

Figure 4 Time-series plot for "SBSD" Variable



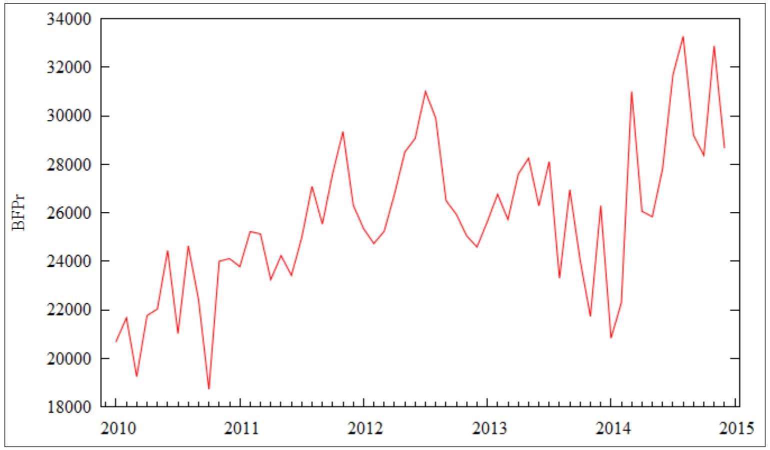
Source: Gretl Software

Figure 5 Time-series plot for "AvSal" variable



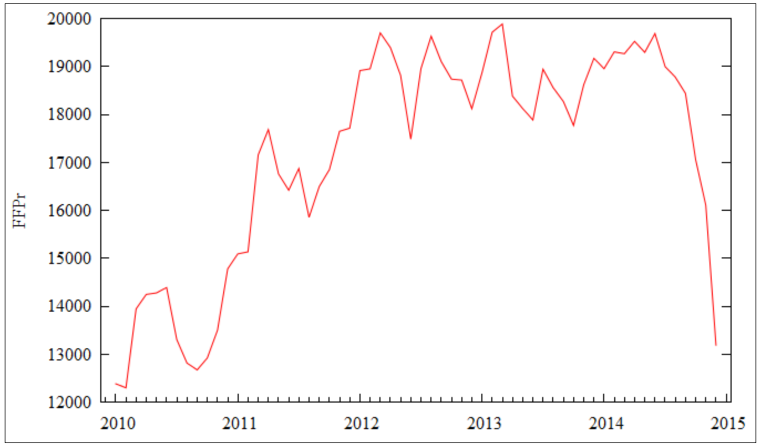
Source: Gretl Software

Figure 6 Time-series plot for "BFPr" variable



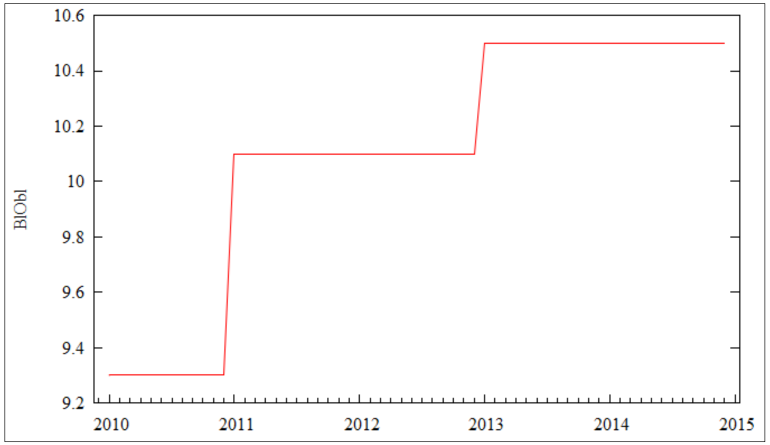
Source: Gretl Software

Figure 7 Time-series plot for "FFPr" variable



Source: Gretl Software

Figure 8 Time-series plot for "BlObl" variable



Source: Gretl Software