Dynamics of the Commodity Prices and Quantities: An Analysis using a Dynamic Multiregional CGE Model

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Abstract

This paper presents a dynamic multiregional CGE model. The purpose is to analyze the evolution of prices and quantities of the following commodities: biofuels, motor fuels, agricultural products and crude oil. The structure of the model is chosen to capture main links between the agricultural sector and the sector producing motor fuels and between these sectors and final consumers. The model addresses land competition between food and biofuels, industrial competition between biofuels and fossil fuels and different effects on two types of consumer, i.e. agricultural and non-agricultural household. Furthermore, the regional coverage of the model reflects the international nature of trade with commodities.

In this version of the paper, we investigate the impact of various scenarios on a small open economy. As an exemplar calibration, we consider the Czech Republic, a member of the EU. Our simulations show that the impact differ between two types of households – those working in agriculture and those outside the agriculture.

Key words: Biofuels, Fuels, Food, AGE modeling
J.E.L. Classification: C68, Q18, Q42

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1 Introduction

The protection of the environment has gradually become an important policy topic over the world since 1970s. In the same time, the world was hit by several oil crises resulting in sharp increase in prices of crude oil and leading vast majority of countries to be more aware of their dependency on energy products coming often from politically volatile regions. While following the aims of environmental policy and national oil security supply policy, policymakers have begun to promote the production and the use of biofuels\(^1\). In addition to above mentioned reasons for promotion, the most cited economic advantages of growing biofuel share on the market are creation of outlets for agricultural commodities leading to acceleration of rural development and boost in agricultural employment.

Having in mind mainly their favor effects, the most important world regions began to support the production and/or the use of biofuels. Namely, the European Union declared to substitute 10 % of traditional fossil fuels by biofuels in transport by the year 2020. The U.S., in the American Energy Independence and Security Act, released in 2007, dictate for placement of 15 bn. gallons of biofuel on the U.S. transport market by the year 2015 and 36 bn. gallons by the year 2022. Brazil, as the second biggest bioethanol producer, published its Brazilian Agroenergy Plan for the years 2006-2011, which stipulates to place annually between 20 and 25 % of bioethanol and 5 % of biodiesel on the transport market. Furthermore, China, Australia, Japan and other countries have chosen some mix of biofuel promotional measures\(^2\).

In contrast to studies mentioning favorable impacts of biofuel promotion, there have also appeared voices condemning especially first generation biofuels of having strong adverse impact on prices of food and propellants together with insignificant effects on reductions of GHG emissions.\(^3\) The rapidly increased water demand as well as negative effect on land use and land use change have also been reminded. In addition, there are also doubts about moving the production of biofuels abroad with ambiguous impacts on rural development, especially domestic value added and employment in agriculture. The issue becomes even more significant with growing prices of both food and traditional

\(^1\) Initially, so called first generation biofuels were cited. These biofuels are made from feedstock that can alternatively be used for production of food. Second generation biofuels, on the other hand, are made from bio-wastes, etc. However, the biofuels of this origin are still relatively expensive and their production mostly runs in the framework of pilot projects. The most common first generation biofuels are bioethanol made from sugar cane, sugar beet, wheat, etc. or biodiesel, ie. methyl ester made largely from rapeseed oil.

\(^2\) For more detail, see OECD [37].

\(^3\) Eg. Mitchell [34]
motor fuels.

Therefore, there is a strong need for the EU policymakers to know the relevance and importance of links between agricultural and energy/transport sector and different types of households distinguished by their income and economic sector where they offer their work. The links should be faced not only to possible changes in world price of crude oil but also to potential biofuel promotional settings in the EU region. With respect to specific characteristics of production/use chain of biofuels, economic model shall namely address following issues: the existence of restricted area needed for the production of biofuels, the existence of linkages between main sectors in biofuel production/use chain in the national economy affecting prices in selected sectors and the existence of feedbacks from those production sectors and final markets to agricultural market.

The international dimension of the model should reflect the ability of some regions to affect world price of crude oil and fossil fuels derived from crude oil. Also the international dimension should reflect that the biofuels and their feedstock are largely traded commodities. The nature of technological development, the need to know right time of adoption of some type of biofuel technologies together with oil reserves call for incorporation dynamic features into the model.

As a result, the multi-regional multi-sectoral dynamic computable general equilibrium model with two heterogeneous agents has been chosen for the analysis.

In this version of the paper, we investigate the impact of biofuel promotion policies on a small open economy. As an exemplar calibration, we consider the Czech Republic, a member of the EU. We present results on two simulations: an increase in biofuel feedstock production subsidy for agricultural households and second, the impact in surge in world agricultural prices. Our simulations show that the impact differ between two types of households – those working in agriculture and those outside the agriculture.

This paper is organized as follows: Section 2 is devoted to brief summary of modeling approaches in evaluation of economic effects of biofuel promotional policies. Section 3 briefly shows the main biofuel players in the world biofuel market, Section 4 describes the current version of the model, Section 5 shows exemplar simulations with the current version of the model and the Section 6 concludes.
2 Literature Review

Growing importance of biofuel issue has brought into the field a relatively extensive research during last decade. The demand for the economic research was strengthen by growing prices of food and crude oil in the last decade. Therefore the linkages between food, biofuel and traditional fossil fuel sector are of high policy interest. Hertel and Beckman [23] or Meyer and Thompson [33], for example, investigate impact of different policy set ups on agriculture-energy relationships.

Generally, a relatively brief review of modeling approaches to economic effects of biofuels provide, for example, Rajagopal and Zilberman [43] or Doumax [14]. They divide modeling approaches to economic effects of biofuels among cost accounting models, micromodels of technology adoption and resource allocation, sectoral models and general equilibrium models. Each approach has advantages and disadvantages. The main advantages of CGE approach is to underpin main links between agricultural sector and industry and between agricultural sector, industry and final consumer. Furthermore, the CGE model is well suited to model competition between agricultural commodities the impact on other agents. On the other hand, the CGE models are able to model the signals from other sectors and consumers back to agricultural sector. 4

The applied CGE models usually differ by the treatment of land use. Generally, there are several approaches of incorporating land use issue into general equilibrium models. The straightforward approach consists of direct incorporation of the land use issue into the general equilibrium framework, for example by addressing functional forms of the agricultural sector. Such approach is chosen by Dixon et. al. [13], who assumes homogeneous land as factor of production and applies an economic model of the U.S. economy USAAGE for evaluation effects of setting mandatory blending quotas in the U.S. by the year 2020, or by Kretschmer [25] who uses adjusted international DART model described in Kretschmer [27] for evaluation of economic impacts of 10 % biofuel target in the EU. Similar approach to land use issue is chosen by Arndt [5] who analyzes impacts of increased private investments into biofuel production in Mozambique. While analyzing effects on the land use and agricultural market in the U.S. and in the rest of the world, Reilly and Paltsev [44] describe the incorporation of biomass energy production and competition for land into the world Emissions Prediction and Policy Analysis (EPPA) model 5. A relatively new biofuel technologies are modeled via so called latent technology approach 6.

4 The summary of CGE models applied on biofuel issue provide, for example, Kretschmer and Peterson [25], Palatnik and Roson [39] or Hertel et. al. [22]
5 In addition to utilization the biofuels in transport, they also consider the biomass burnt for production of electricity.
6 Latent technologies are usually existent in current time but are too expensive to be
Perry et. al. [42] carry out the analysis of response of the Argentine economy to a boost in the global demand for biofuels and their feedstock. They run two scenarios with fixed amount of the land as input of production and scenario allowing for increase of available land. While they enrich the initial G-Cubed model McKibbin and Wang [31] also assume homogeneous land.

The issue of restricted area and its utilization can also be addressed by incorporating the constant elasticity of transformation (CET) function into the model allowing landowners for choosing the optimal utilization of restricted land area according to its yields and usage. Such approach use Hertel and Tsi-gas [19] who analyze effects of the elimination of farm and food tax preferences on the US economy in 1997. Hertel [18] also follows this land use modeling approach and analyzes the effects of agricultural policies on commodity trade and markets with the help of GTAP model, Timilsina et. al. [50] analyze long-term impacts of large-scale expansion of biofuels on land-use change, food supply and prices in various countries. Banse et. al. [6] use more elaborated system of constant elasticity transformation functions that take 3-level nesting structure and extend the GTAP–E model. The model is employed in analysis of impacts of mandatory blending quotas of the European Biofuel Directive.8

More comprehensive CGE models assume heterogeneous types of land9 or divide regions into so-called agro-ecological zones or interconnect detailed bottom-up land use models with top-down CGE models10.

### 3 Biofuel Market

The main two types of first generation biofuels are biodiesel11 which serves as substitute to diesel and bioethanol12 substituting gasoline on the market. The

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7 Multiregional intertemporal world CGE model
8 Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport.
9 See for example Abdegalil and Cohen [1] or Abdula [2]
10 See for example, Ronneberger et. al. [45], [46], Lee et. al. [29], or Bosello and Zhang [10]
11 This is common name for all Fatty Acid Methylesters. The methylesters are usually produced from rapeseed oil, palm oil, sunflower oil, jatropha oil, etc.
12 Bioethanol is usually produced from a variety of feedstock such as sugar cane, sugar beet, sorghum, corn, wheat, etc.
importance of biofuel market over the world has been sharp increasing. The world biodiesel production grew about 861 % and world bioethanol production increased by 285 % between the years 2003 and 2009 (see Figures (2) and (3)).

Figure (4) displays the structure of biodiesel production. The largest part of biodiesel is produced in the EU countries, mainly Germany, France, and Italy. The role of biodiesel has been gradually growing also in other world regions. The U.S. witnesses large increases in production of biodiesel from the year 2005 and the production in 2008 is approximately 50 times higher than in the year 2000. Further, as mentioned, Brazil also declared its aim to promote the production of biodiesel and as a result, its production significantly grew in 2006-2008. The same holds for Argentina, Malaysia and China, as examples of Asian countries, also produce indispensable part.

Looking at the situation in the EU27 more comprehensively, we see that the EU biodiesel production represented approximately 96 % of world biodiesel production in 2003. Since also other world regions begun to produce biodiesel, the EU27 share has decreased to approximately 56 %. The largest biodiesel producers in the EU in 2009 are Germany (29.6 % of the EU production), France (23.8 %), Italy (7.6 %) and Spain (6.4 %). The share of the Czech Republic in the EU biodiesel production declined from 6.5 % to 1.75 % between 2003 and 2009. There were several reasons for this decline and one of them was absence of biofuel promotional framework in the years 2007 and 2008.

The structure of production of bioethanol in the world is shown in Figure 5. It can be clearly seen that the most important bioethanol producers are the U.S. and Brazil. In both countries, the production of bioethanol has still been growing. However, as a result of sharp increases in the U.S. bioethanol production, the U.S. outweighed production of Brazil in the year 2006. In the 2009, the U.S. bioethanol industry manufactured approximately 54 % of world production, the Brazil produced around 34 % and the EU27 represented only 4.7 % of world bioethanol industry.

Looking deeply at EU27 bioethanol structure, the biggest EU27 bioethanol producer in 2009 is France (34.7 % of the bioethanol production of the EU27), Germany (21 %), Spain (12.7 %) and Sweden (4.9 %). The Czech Republic produces around 3 % of the EU 27 bioethanol, which is relatively significant number comparing to its population.

4 The Structure of the Model - The Competitive Economy

Each region is endowed with an arable land $L$, populated by two representative agents: agricultural and non-agricultural households. The economy is divided
into four main sectors: final good producing sector, motor fuel producing sector, agricultural sector producing either food or biofuel feedstock, and for the relevant regions oil extracting sector. The model is divided among seven aggregated world regions: the Czech Republic, the rest of EU-27, the OPEC countries, the rest of the OECD, the former USSR without Baltic states, the rest of Asia, Africa, and the rest of Americas. While using the same land as a production factor, the agricultural sector is quasi-divided between production of food and production of biofuel feedstock. In this version, we assume a fixed amount of agricultural land in each region.

4.1 Households

As regards households, both representative agents consumes a final good $C_{i,t}$, food $A_{i,t}$, public good $G_{i,t}$, and supplies an elastic amount of labor $L_{i,t}$. There are two types of households in the economy: the agricultural and the non-agricultural household. The non-agricultural household maximizes in each region its utility function over infinite time horizon. Nevertheless the optimization problem is in the case of non-agricultural household more ”dynamic” than in the case of agricultural household. It is because of presence of capital over which the non-agricultural household optimizes and that brings her future income.

4.1.1 Non-agricultural Household

The non-agricultural household maximizes the expected discounted sum of momentary utilities $u$ over the infinite horizon (eq. 1) and is constrained by inter-temporal budget constraint (eq. 2) and law of motion (eq. 3). The household enjoys the private consumption of non-food products $C_{h,i,t}$, the consump-

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13 For exact division of the countries see Table 6
14 The division of the regions reflects the economic structure of relevant countries, ability to affect world price of food and crude, which can bring an effect in later versions of the model. For the purposes of the paper, we use economic, agricultural and energy data. The data for world regions comes mainly from the World Bank (economic and agricultural data) and the Energy Information Administration (production and consumption of biofuels). However, there are some inconsistencies in the data that has to be checked. This holds namely for the former USSR and African countries.
15 Looking at the data, we see that at least in the period 2003-2008 for the EU27 region, this is a reasonable assumption. See Figure 1. The annual changes are relatively small and the EU27 witnesses even decline in agricultural land. In the extended version of the model, the assumptions about possible increases in agricultural land will be made.
tion of food $A_{h,i,t}^h$, and dislikes the work effort $L_{h,i,t}^h$. The maximization problem of the non-agricultural households can technically be written as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t u \left( C_{h,i,t}^h, A_{h,i,t}^h, L_{h,i,t}^h \right),$$

subject to:

$$W_{i,t+1} + C_{h,i,t}^h \left( 1 + \tau_{vat_{i,t}} \right) + \pi_{i,t}^a A_{h,i,t}^h \left( 1 + \tau_{vatA_{i,t}} \right) + I_{i,t} + \phi (I_{i,t}, K_{i,t}) \leq$$

$$\leq w_{h,i,t}^h L_{i,t}^h \left( 1 - \tau_{l_{i,t}} \right) + \Pi_{i,t}^h \left( 1 - \tau_{p_{i,t}} \right) + (1 + r_{i,t}) W_{i,t},$$

$$K_{i,t+1} = (1 - \delta) K_{i,t} + I_{i,t},$$

where $E_0$ is the expectation operator, $C_{h,i,t}^h$ is the consumption of final good by non-agricultural household, $A_{h,i,t}^h$ is the food consumption by non-agricultural household, $L_{h,i,t}$ is elastic amount of work, $W_{i,t}$ is the regional net wealth, $I_{i,t}$ are investments to the final good sector, $K_{i,t}$ is its capital stock, $\pi_{i,t}^a$ is the real food price, $r_{i,t}$ is the real interest rate, $w_{h,i,t}^h$ is high income wage received by non-agricultural household and $\Pi_{i,t}^h$ is profit realized by the final good sector, which is assumed to be income of non-agricultural household$^{16}$. The parameter $\beta \in (0; 1)$ represents the inter-temporal rate of substitution, and $\phi (I_{i,t}, K_{i,t})$ adjustment cost function. The tax-policy parameters are $\tau_{vat_{i,t}} \in (0; 1)$ representing standard value added tax rate, the value added tax rate (it may differ from the standard VAT rate) $\tau_{vatA_{i,t}} \in (0; 1)$, the profit tax rate $\tau_{p_{i,t}}$ and the labor tax rate $\tau_{l_{i,t}} \in (0; 1)$. In the formula above, as well as in all subsequent formula, the subindex $i$ refers to regions, while the subindex $t$ refers to time.

The momentary utility function is assumed to have the following form: $u_t = \left( \ln C_{h,i,t}^h + \xi_{ha} \ln \left( A_{h,i,t}^h - \bar A \right) - \xi_{hl} \frac{1}{\phi_h} \left( I_{h,i,t}^h \right)^{\phi_h} \right)$, cost adjustment function is assumed to be: $\phi (I_{i,t}, K_{i,t}) = \frac{\varphi}{2} \left( \frac{I_{i,t}}{K_{i,t}} - \delta \right)^2 K_{i,t}$ and household’s optimization implies therefore the following optimality conditions:

$$C_{h,i,t}^h \left( 1 + \tau_{vat_{i,t}} \right) = \frac{1}{\xi_{ha}} \left( A_{h,i,t}^h - \bar A \right) \pi_{i,t}^a \left( 1 + \tau_{vatA_{i,t}} \right),$$

$$C_{h,i,t}^h \left( 1 + \tau_{vat_{i,t}} \right) = \frac{1}{\xi_{hl}} \left( L_{i,t}^h \right)^{\phi_h - 1} w_{h,i,t}^h \left( 1 - \tau_{l_{i,t}} \right),$$

$$C_{h,i,t+1} \left( 1 + \tau_{vat_{i,t+1}} \right) = \beta C_{h,i,t}^h \left( 1 + \tau_{vat_{i,t}} \right) \left( 1 + r_{i,t+1} \right),$$

$$1 + \varphi \left( \frac{I_{i,t}}{K_{i,t}} - \delta \right) =$$

$$\Pi_{i,t}^h = K_{i,t}^\alpha L_{i,t}^{\lambda_y} F^{-1-\alpha_y-\alpha_h} - w_{h,i,t}^h L_{i,t}^y - F_{i,t} \left( \pi_{i,t}^f + \tau_{vat} \right)$$

$^{16}$
\[
\frac{1}{1 + r_{t+1}} \left[ \frac{\alpha_k}{K_{i,t+1}} Y_{i,t+1} (1 - \tau_{i,t+1}^p) - \frac{\varphi}{2} \left( \delta^2 - \frac{I_{i,t+1}^2}{K_{i,t+1}^2} \right) + (1 - \delta) \left( 1 + \varphi \left( \frac{I_{i,t+1}}{K_{i,t+1} - \delta} \right) \right) \right].
\]

4.1.2 Agricultural Household

The agricultural household maximizes a similar utility function as the other household, however she does not accumulate assets such as physical capital or net foreign wealth. Therefore, she is constrained by rather intra-temporal budget constraint (eq. 2). The agricultural household problem reads as follows:

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t u \left( C_{i,t}^a, A_{i,t}^a, L_{i,t}^a, L_{i,t}^b \right), \tag{8}
\]

subject to:

\[
C_{i,t}^a (1 + \tau_{i,t}^v) + \pi_{i,t}^a A_{i,t}^a \left( 1 + \tau_{i,t}^v A_{i,t} \right) \leq w_{i,t}^a L_{i,t}^a \left( 1 - \tau_{i,t}^l \right) + \Pi_{i,t}^a \left( 1 - \tau_{i,t}^p \right), \tag{9}
\]

where \( C_{i,t}^a \) is consumption of final good realized by agricultural household, \( A_{i,t}^a \) is consumption of food realized by agricultural household, \( L_{i,t}^a \) is the amount of work offered by the agricultural household, \( w_{i,t}^a \) is the wage in the agricultural sector, \( \Pi_{i,t}^a \) is the agricultural profit.

The first order conditions are given as follows:

\[
\frac{\left( A_{i,t}^a - \bar{A} \right)}{C_{i,t}^a} = \frac{(1 + \tau_{i,t}^v)}{(1 + \tau_{i,t}^v A_{i,t}^a)} \xi_{aa}, \tag{10}
\]

\[
\left( L_{i,t}^a \right) \phi_a = \frac{w_{i,t}^a \left( 1 - \tau_{i,t}^l \right)}{C_{i,t}^a \left( 1 + \tau_{i,t}^v A_{i,t}^a \right)} \xi_{al}. \tag{11}
\]

4.2 Firms

There are four sectors in the economy: the final good sector, fuel-producing sector, agricultural sector producing either food or biofuel feedstock and for relevant regions oil-extraction sector.

4.2.1 Final Good Sector

The sector producing final goods uses for its production capital, fuels (energy), and labor supplied by non-agricultural households. Because final good sector produces only one type of good with price normalized to unity, the
maximization problem of this sector can be written as follows:

\[
\max \ Y (K_{i,t}, \zeta_{i,ly} L^y_{i,t}, F_{i,t}) - w^h_{i,t} L^y_{i,t} - F_{i,t} \left( \pi^f_{i,t} + \tau_{i,t} \right),
\]

(12)

where \( Y \) is final good production function, \( F_{i,t} \) are motor fuels consumed by final good sector in considered region, \( L^y_{i,t} \) is labor supplied by non-agricultural household and employed in production of final good, \( w^h_{i,t} \) is higher income wage and \( \pi^f_{i,t} \) is a price of motor fuels. Labor productivity in the region \( i \) is given by \( \zeta_{i,ly} \) and \( \tau_{i,t} \) stands for excise fuel taxation.\(^{17}\)

The production function is assumed to be given as \( Y_{i,t} = K^\alpha k_{i,t} \zeta_{i,ly} L^y_{i,t} \alpha_{ly} F_{i,t} \left( 1 - \alpha_{ly} - \alpha_k \right) \) and the standard cost minimization implies the following formula:

\[
\alpha_{ly} Y_{i,t} = w^h_{i,t} L^y_{i,t},
\]

(13)

\[
(1 - \alpha_k - \alpha_{ly}) Y_{i,t} = F_{i,t} \left( \pi^f_{i,t} + \tau_{i,t} \right),
\]

(14)

\[
\Pi^h_{i,t} = K^\alpha_k \zeta_{i,ly} L^y_{i,t} \alpha_{ly}^{1/\alpha_k} F_{i,t}^{1-\alpha_{ly} - \alpha_k} - w^h_{i,t} L^y_{i,t} + F_{i,t} \left( \pi^f_{i,t} + \tau_{i,t} \right).
\]

(15)

4.2.2 Fuel Producing Sector

The sector producing fuels uses for its production crude oil and biofuel feedstock as an alternative input. Since the sector produces only one output, the maximization problem can be read as follows:

\[
\max \pi^f_{i,t} \mathbb{F}^d (O_{i,t}, \zeta_{i,b} B_{i,t}) - \pi^o_{i,t} O_{i,t} - \pi^a_{i,t} B_{i,t},
\]

(16)

where \( \mathbb{F}^d \) is production function in fuel sector, \( O_{i,t} \) is crude oil used for production of motor fuels, \( B_{i,t} \) is biofuel feedstock used for production of motor fuels, \( \zeta_{i,b} \) is the technological improvement in used of biofuel feedstock, and \( \pi^o_{i,t} \) is price of crude oil. The production function is assumed to be of a CES form:

\[
\mathbb{F}^d_{i,t} = \left[ \left( \alpha_o O^{-\rho_f}_{i,t} + (1 - \alpha_o) \zeta_{i,b} B^{-\rho_f}_{i,t} \right) \right]^{\frac{1}{\rho_f}}
\]

and the first-order conditions imply:

\[
\frac{\pi^0_{i,t}}{\pi^o_{i,t}} = \frac{\alpha_o}{1 - \alpha_o \zeta_{i,b}} \left( \frac{B_{i,t}}{O_{i,t}} \right)^{1+\rho_f},
\]

(17)

\[
\frac{\pi^f_{i,t}}{\pi^f_{i,t}} = \alpha_o \left( \frac{F^d_{i,t}}{O_{i,t}} \right)^{1+\rho_f}.
\]

\(^{17}\)Note that this is a unit tax rather than an ad valorem tax.
4.2.3 Agricultural Sector

The agricultural sector produces two types of output: food and biofuel feedstock that is consequently utilized in the production of motor fuels. Both types of production share a fixed amount of land and there is a constant-elasticity of transformation function, which divides the agriculture output into food and biofuel feedstock. Therefore, the agricultural sector problem is as following:

$$\max \pi z_{i,t} A^d \left( \zeta L^a_{i,t}, L^a_{i,t} \right) - w^a_{i,t} L^a_{i,t} - \pi^l L^a_{i,t},$$

(19)

where $\pi z_{i,t}$ is the shadow price of the agriculture output (defined below), $L^a_{i,t}$ is the labor used, $L^a_{i,t}$ is the land used and $\pi^l$ is the rental rate of land. We assume that the land is owned by agricultural household. Since the production function is assumed to have constant-returns-to-scale, the profit is given by the land rate $\Pi^a_{i,t} = \pi^l L^a_{i,t}$.

The CET assumption means that the agricultural production is divided into the two output based on price ratio, i.e., the fraction of the output used for food is given by $\alpha_T \left( \frac{\pi^a_T}{\pi^b_T (1 + \tau_{sub}^i t)} \right)^{1+\varrho_T}$, where $\left(1 + \tau_{sub}^i t\right)$ is the subsidy for biofuel feedstock producers, and $\alpha_T \in (0, 1)$, $\pi^b_T$ is price of biofuel feedstock and $\varrho_T > -1$ are parameters of the CET function. The shadow price of the agricultural output is then given as follows:

$$\pi z_{i,t} = \frac{\pi^a_T \left(1 + (1 - \alpha_T) \left(1 + \tau_{sub}^i t\right)\right)}{1 + \alpha_T \left( \frac{\pi^a_T}{\pi^b_T (1 + \tau_{sub}^i t)} \right)^{1+\varrho_T}}.$$

The following equations characterize the agriculture producer’s optimum:

$$\frac{\pi z_{i,t}}{w^a_{i,t}} = \frac{L^a_{i,t}}{A^d \alpha_a},$$

(20)

$$\frac{\pi^a_{i,t}}{\pi^l_{i,t}} = \frac{L^a_{i,t}}{A^d \left(1 - \alpha_a\right)},$$

(21)

As the land is in the fixed supply, this determines the rental rate $\pi^l$.

4.3 Oil-producing Regions

Oil producing region produces crude oil (extraction) by using sectoral specific labor and capital, i.e. $O^e_{i,t} = \chi(K^o_{i,t}, L^e_{i,t}, O^e_{i,t})$ and controls its oil reserves, i.e. $R_{i,t+1} = R_{i,t} - O^e_{i,t} + \zeta^f_{i,t}$. 
In the preceding equations $R_{i,t}$ are regional oil reserves, $\zeta_{i,t}$ are shocks to oil reserves (such as new discoveries), the function $\chi(K_{i,t}^o, L_{i,t}^o, O_{i,t}^o)$ captures the notion that it is costly to extract the oil and that capital and labor should be used. The sector specific capital used in the oil extracting industry cannot be easily transferred to the final good sector which leads to sluggish adjustment of oil supply to its prices, i.e. a feature observed in reality.

The solution of oil-producing region problem leads to modified Hotelling’s rule:

$$\pi_t u_{ct} \chi_{Ot} = \beta E_{t+1} u_{ct} \pi_{t+1} \chi_{Ot+1},$$

where $\chi_{Ot}$ are marginal extraction costs. The domestically extracted oil $O_{i,t}^d$ can be used either domestically $O_{i,t}$ or can be exported $O_{i,t}^x$.

### 4.4 International Trade

All relevant commodities are assumed to be traded via international markets. Therefore, following equations has to be satisfied:

$$F_{i,t}^d = F_{i,t} + F_{i,t}^x \quad (22)$$

where $F_{i,t}^d$ are net exports of fuels from considered region $i$, $F_{i,t}^d$ is domestic production of fuel producing sector and $F_{i,t}$ is consumption of fuels by final good producing sector.\(^{19}\) agricultural products used for biofuel production:

$$A_{i,t}^d = A_{i,t}^a + A_{i,t}^b + A_{i,t}^x \quad (23)$$

where $A_{i,t}^f$ is net export of food from considered region $i$, $A_{i,t}^d$ is domestic production of food, $A_{i,t}^p$ is consumption of food by agricultural household and $A_{i,t}^p$ is a consumption of food by non-agricultural household.

$$B_{i,t}^d = B_{i,t} + B_{i,t}^x \quad (24)$$

where $B_{i,t}^x$ are net exports of biofuels/feedstock from considered region $i$, $B_{i,t}^d$ is domestic production of biofuel feedstock and $B_{i,t}$ is consumption of bifuel feedstock by fuel sector.

$$O_{i,t} = O_{i,t}^d - O_{i,t}^x \quad (25)$$

\(^{18}\)If the crude oil were extracted costless, equation would imply the standard Hotelling rule ($\pi_t = \beta E_{t+1} u_{ct+1} \pi_{t+1}$), which dictates that the price of an exhaustible asset should growth at the rate of inter-temporal substitution.

\(^{19}\)Note that motor fuels are not consumed by final consumers, which is one of the possible extensions of the model.
where $O_{i,t}^x$ is net export of oil from considered region $i$, $O_{i,t}^d$ is domestic production of crude oil and $O_{i,t}$ is consumption of crude oil by fuel sector. For oil non-producing country holds: $O_{i,t}^d = 0$ and therefore $O_{i,t} = -O_{i,t}^x$.

The GDP identity respecting amount of net exported final good $X_{i,t}$ has to be satisfied:

$$C_{i,t}^a + C_{i,t}^h + G_{i,t} + I_{i,t} + \phi(I_{i,t}, K_{i,t}) + X_{i,t} = Y_{i,t}$$

The international market clearing is given as follows:

$$\sum_{i \in I} X_{i,t} = 0,$$
$$\sum_{i \in I} A_{x,i,t}^e = 0,$$
$$\sum_{i \in I} O_{x,i,t}^e = 0.$$  

These equations will determine the international relative prices $\pi^a_t$, $\pi^o_t$ and the world interest rate $r_t$. By virtue of the Walras law, also $\sum_{i \in I} [W_{i,t+1} - (1 + r_t)W_{i,t}] = 0$.

### 4.5 Public Sector

For each country, following equality for government debt $\Delta_{i,t}$ has to be satisfied:

$$\Delta_{i,t+1} = \Delta_{i,t} (1 + r_t) + G_{i,t} + B_{i,t}^d \tau_{i,t}^{sub} -$$
$$- \tau_{i,t}^{vat} (A^a_{i,t} + A^h_{i,t}) - \tau_{i,t}^{vat} A^a_{i,t} \pi^o_t (A^a_{i,t} + A^h_{i,t}) - \tau_{i,t}^{ex} F_{i,t} - \tau_{i,t}^{l} (L_{a,i,t}^a + L_{b,i,t}^b + L_{y,i,t}^y).$$

### 5 Illustrative Simulations

In this version of the paper, we consider the impact on biofuel promotion policies on a small open economy. As an exemplar calibration, we consider the Czech Republic. We present results on three simulations: an increase in biofuel
feedstock production subsidy for agricultural households in the Czech Republic, second the impact in surge in world oil price, and finally, the exogenous technological shift $\zeta$ in the fuel producing sector.

First, we consider the impact on production subsidy for agricultural households to motivate them to produce biofuel feedstock. This is done in several steps. First, we consider the counterfactual situation as if there were no government budget constraints. Second, we consider a more plausible scenario, that the government must balance the budget and we consider the scenario where the balance is done using the increase in labor taxation. Both scenarios consider the gradual increase in subsidy so that it increases up to 10% of the current price of biofuel feedstock. Figures 6 and 7 show the results as the percentage deviation from the initial steady state.

If the government budget is not considered, we see that there is a positive impact on agricultural households (their wages, consumption, and agricultural consumption boost), while the impact on the other households is negligible. The reason for this small impact is that the non-agricultural household is somehow insulated from the price impact of subsidy as the considered economy is small and is price taker. The impact on the external position of the economy is positive: its net exports boost, which is caused by boosting non-agriculture exports and biofuel feedstock exports, while the food net exports fall. The fall is caused by the switch of the agriculture production from the food to biofuel feedstock. The same can be said about the GDP structure.

However, if the government budget has to be balanced by the increase in labor taxation, the situation is different. Both households are now negatively affected as higher labor taxes have distortional effects on the labor supply. The consumption of both household falls, but the fall is smaller for agricultural households, where the effect is somehow counterbalanced by the production subsidy. The exports of all goods, except of biofuel feedstock, fall, as well as the value added created in the relevant sectors.

Our simulations show two important lessons: (1) the impact of policy may differ between two types of households: those working in agriculture and those outside the agriculture; (2) if the production subsidy is considered, it may imply negative effects on average for all households, even for those working in the agriculture. This second result is due to the openness of the economy, which implies that some of the potential benefits of the subsidy just fly from the country to the rest of the world.

The second simulation aims at the effect of the increase in the world oil price. We consider the increase by 20% accompanied by the TFP productivity ($\zeta_{ty}$ growth of 5%). One can consider the TFP growth as a response of the economy to high commodity prices, although we do not explicitly model here the
mechanism. Figures 8 and 9 show the results as a deviation from the original steady state. Figure 8 does not consider the effect on the budget, while Figure 9 assumes that the government manipulates the labor tax to balance the budget.

The effects of this scenario is non-linear. We see that first the economy is negatively affected by high oil prices, but the effect on the agricultural sector is small as two effects almost cancel each other: on one hand, the high oil price means low demand, on the other hand, it means higher demand for biofuel feedstock. But, finally, the effect of higher TFP starts to have an impact and alleviates the impact of high oil prices. This scenario has, however, a persistent effect on the structure of the Czech exports: it boosts agriculture exports, but diminishes non-agricultural exports. The scenario with the reaction of the government has similar effects, but the difference between the two sector is more pronounced.

Finally, the last simulation asks what would happen if the productivity parameter $\zeta_{b,i}$ in the fuel sector in the Czech Republic rises. Figures 10 shows the results. One can interpret this scenario as an efficiency gain in using biofuel feedstock in producing motor fuel. Surprisingly, such a scenario does not benefit the agriculture sector as its prices are internationally determined. It, however, benefits the other sector, as it can use cheaper fuels. Consequently, the wealth, consumption, and the real wage of the non-agriculture household increase. Similarly to the first scenario, any possible benefits for the agricultural sector fly from the Czech Republic to the rest of the world. However, the wage increase in the non-agricultural sector means that the government may decrease the labor tax (see Figure 11) to keep the budget revenues intact. If it does so, then also the agricultural sector and households would benefit.

6 Conclusion

This paper introduces the description of the CGE model. The structure of the model is chosen to capture main links between the agricultural sector and the sector producing motor fuels and between these sectors and final consumers. The model addresses land competition between food and biofuels, industrial competition between biofuels and fossil fuels and different effects on two types of consumer, i.e. agricultural and non-agricultural household. Furthermore, the regional coverage of the model reflects the international nature of trade with commodities. We have investigated the impact of various scenarios (biofuel promotion subsidy, world oil price, and the technological progress) on a small open economy – the Czech Republic, a member of the EU.

Our simulations tell two important messages: first, the impact of various sce-
narios differ between the two types of households, sometimes in a non-intuitive way. Second, if a policy is introduced in a small open economy unilaterally, it may hurt the economy, as potential benefits may fly to the rest of the world.

Acknowledgements

The research on this paper has been supported by the grant of the Grant Agency of the Czech Republic No. 402/11/2500. The support is gratefully acknowledged.

References


Table 1: Division of the world.

<table>
<thead>
<tr>
<th>Region</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>the Czech Republic</td>
<td>the Czech Republic</td>
</tr>
<tr>
<td>the rest of EU 27</td>
<td>Austria, Belgium, Bulgaria, Cyprus, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Ireland, Italy, Lithuania, Latvia, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Sweden, Malta</td>
</tr>
<tr>
<td>rest OECD</td>
<td>Australia, Canada, Switzerland, Iceland, Japan, Korea, Mexico, Norway, New Zealand, Turkey, United States</td>
</tr>
<tr>
<td>OPEC countries</td>
<td>Angola, United Arab Emirates, Algeria, Ecuador, Iran, Iraq, Kuwait, Lybia, Nigeria, Quatar, Saudi Arabia, Venezuela</td>
</tr>
<tr>
<td>former USSR</td>
<td>Azerbaian, Belarus, Georgia, Kazakhstan, Russia, Ukraine, Uzbekistan</td>
</tr>
<tr>
<td>rest Asia</td>
<td>Bangladesh, China, Hong Kong, Indonesia, India, Lebanon, Sri Lanka, Malaysia, Oman, Pakistan, Philippines, Singapore, Syrian Arab Republic, Thailand, Vietnam, Yemen</td>
</tr>
<tr>
<td>Latin America</td>
<td>Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Guatemala, Honduras, Jamaica, Panama, Peru, Puerto Rico, Paraguay, El Salvador, Uruguay</td>
</tr>
<tr>
<td>rest Africa</td>
<td>Botswana, Cote d’Ivoire, Cameroon, Egypt, Ethiopia, Kenya, Morocco, Sudan, Tunisia, Tanzania, South Africa, Congo, Zambia, Zimbabwe</td>
</tr>
</tbody>
</table>

Fig. 1. Agricultural land in the EU27, *(Source: World Bank)*

![Graph of agricultural land in the EU27](image)
Fig. 2. World Biodiesel Production, \textit{(Source: U.S. Energy Information Administration)}

Fig. 3. World Bioethanol Production \textit{(Source: U.S. Energy Information Administration)}
Fig. 4. Structure of Biodiesel Production (Source: U.S. Energy Information Administration)

Fig. 5. Structure of Bioethanol Production (Source: U.S. Energy Information Administration)
Fig. 6. Scenario: increase in biofuel production subsidy

Fig. 7. Scenario: increase in biofuel production subsidy balanced by an increase in labour taxation
Fig. 8. Scenario: increase in oil price

Fig. 9. Scenario: increase in oil price; budget balanced
Fig. 10. Scenario: increase in $\zeta_b$ productivity (fuel producing sector)

Fig. 11. Scenario: increase in $\zeta_b$ productivity; the budget balanced