Economic Effects of Biofuel Promotion. An Assessment with a World Dynamic Computable General Equilibrium Model

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The paper is contributed to honor Osvald Vasicek. Osvald has a long and productive career as an academic and a teacher. One of the authors of this paper (Jan) was a student at the Masaryk University and under Osvald's continuous support and encouragement he started to study and apply methods of dynamic system theory, stochastic filtering, stochastic control, and numerical methods to economic problems. Without his support and encouragement, his beginnings in these fields were certainly much harder. Now, as Jan get older, he tries to transmit his knowledge to next students, although Jan's knowledge and pedagogical skills cannot match that of Osvald.

In this paper, authors apply those skills, especially from stochastic control and numerical mathematics, in which Jan was initiated under Osvald's guidance, to an important problem of public finance and environmental economics. As the other author (Vitezslav) is now a student of Jan, this paper is a small witness of how tireless Osvald's support as an academic and a teacher has influenced the economic research in the Czech Republic in various areas. In fact, it would be hard to overestimate Osvald's contribution to Czech academia. Let us conclude these paragraphs by expressing the deep feeling that the authors are much obliged to Osvald and his colleagues as they have been excellent scholars, inspiring teachers, and great personages.

Abstract

The promotional policies targeted at alternative fuels take different forms and are currently a very important policy issue integrating the environmental, economic, and fiscal concerns. While choosing different environmental policy mixes, almost all important world regions support production and use of biofuels. This paper introduces the first version of the computable general equilibrium (CGE) model aiming at the analysis of promotional policies focused on the first generation biofuels over the world. The model is suited for evaluation of impacts of such policies on the economy of the Czech Republic. The main features of the model, ie. multiregionality, intertemporality, and a quasi-fixed land supply (limited area of agricultural land as one of the production input of agricultural sector) deliberately adress the structure and nature of biofuel market. Countries are properly aggregated in order to underpin production and trade of biofuels over the world and also the ability of regions to affect world price of crude oil. The sectors has been selected in order to know the links in biofuel production use chain and process of creation of prices in fuel and agricultural sector. The paper presents exemplar simulations with the core of the model.

Key words: Biofuels, CGE modeling, Land Use
J.E.L. Classification: C68, Q18, Q42

1 Introduction

The protection of the environment has gradually become an important policy topic over the world since 1970s. While following the aims of environmental policy, mainly reduction of GHG emissions, policymakers have recently begun to promote the production and the use of biofuels.[1] In addition to favor environmental effects, the most cited economic advantages of growing biofuel share on the market are creation of outlets for agricultural commodities and consequent support of rural development, employment in agriculture and weakening the dependency of economies on fossil fuel sources coming usually from politically volatile regions.

Taking in mind the above mentioned favor effects, the most important world regions began to support the production and/or the use of biofuels. 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. 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.

Therefore, there is a strong need for policymakers to know the impacts of

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[1] Firstly, so called first generation biofuels were cited. These biofuels are, however, made from feedstock that can alternatively be used for production of food. On the other hand, so called second generation biofuels are made from bio-wastes, etc. However, these types of biofuels are relatively expensive and currently their production can not be commercially processed. The most common first generation biofuels are bioethanol made from sugar cane, sugar beet or wheat or biodiesel, ie. methyl ester made from rapeseed oil.

[2] For more detail, see OECD [34].

chosen biofuel support scheme mix, especially on economic variables like employment, value added and selected prices. 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 production of biofuels, the existence linkages between main sectors in biofuel production/use chain in the national economy affecting prices in selected sectors and the existence 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 special treatment of oil reserves call for incorporation dynamic features into the model. As a result, the multi-regional multi-sectoral dynamic computable general equilibrium model has been chosen for the analysis.

This paper is organized as follows: Section 2 is devoted to brief summary of CGE models aimed at assessing biofuel promotional policies. Section 3 describes the current version of the model, Bellman's equation and solution of the model for oil producing country. Section 4 shows an exemplar simulation with the current version of the model, while section 5 concludes by mentioning future extension of current version of the model.

2 Biofuel Issue in CGE Models

Because the issue of biofuel promotion has gradually become very important, there can be seen attempts to incorporate the topic into general equilibrium framework[3].

Generally, there are several approaches of incorporating land use issue into general equilibrium models. The straightforward approach consists of incorporation of the land use issue into the general equilibrium framework, for example by addressing functional forms of the agriculture sector, for example, by treatment of land as homogeneous factor of production. Such approach is chosen by Dixon et. al. [12], who apply an economic model of the U.S. economy USAGE for evaluation effects of setting mandatory blending quotas in the U.S. by the year 2020, or by Kretschmer [24] who uses adjusted international DART model described in Kretschmer [26] for evaluation of economic impacts of 10 % biofuel target in the EU. Similar approach to land use issue

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[3] See for example Kretschmer and Peterson [24], Palatnik and Roson [36] or Hertel et. al. [21] for relatively exhausting review.

is chosen by Arndt [4] who analyzes impacts of increased private investments into biofuel production in Mozambique. To analyze effects on the land use in the U.S. and the rest of the world, Reilly and Paltsev [41] describe the incorporation of biomass energy production and competition for land into the world Emissions Prediction and Policy Analysis (EPPA) model [4]. A relatively new biofuel technologies are modeled via so called latent technology approach [5]. Perry et. al. [39] carry out the analysis of response of the Argentine economy to a boost in the global demand for biofuels and their feedstocks. 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 [6] McKibbin and Wang [30] 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 Tsigas [18] who analyze effects of the elimination of farm and food tax preferences on the US economy in 1997. Hertel [17] 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. Banse et. al. [5] 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 [7].

Therefore, more complicated models assume heterogeneous types of land [8] or divide regions into so-called agro-ecological zones or interconnect detailed bottom-up land use models with top-down CGE models [9]. These models are usually very data demanding and/or they are limited in dynamics because of their relatively high disaggregation.

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[4] In addition to utilization the biofuels in transport, they also consider the biomass burnt for production of electricity.

[5] Latent technologies are usually existent in current time but are too expensive to be utilized. While the economy develops, the latent technology become profitable. Their incorporation is usually common in dynamic models. Modeling latent technologies needs the data on the input and cost structures of the different types of production of biofuels and mark-up between production costs and prevalent fuel prices. For example the production of second generation biofuels can be modeled in this way.

[6] Multiregional intertemporal world CGE model

[7] Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport.

[8] See for example Abdegalil and Cohen [1] or Abdula [2]

[9] See for example, Ronneberger et. al. [42], [43], Lee et. al.[28], or Bosello and Zhang [9]

To sum up, currently, there exist several approaches to modeling economic impacts of biofuel support in the world via CGE models. These models are aimed at the EU, the US economy as well as developing countries. A significant part of CGE models applied on the issue of biofuels analyze introduction of some level of mandatory substitution of traditional fossil fuels by biofuels. The most inspected impacts are price effects, mainly on agricultural commodities and food but the are also to explain impacts on value added, trade and employment. The land use issue is treated in different ways, ie. by adoption of special functional forms in production, incorporation of CET functions with heterogeneous types of land, incorporation of so called agroecological zones, or setting sophisticated linkage between bottom up land use models and top down CGE models. The following model chooses the way of incorporation of special functional forms into the CGE. The chosen treatment of land use allows for proper incorporation of dynamics into the model and better addresses regional data availability in the world.

3 The Core of the Model

The model is divided among four sectors (agriculture, crude oil extraction, fuel industry and other final good market) and eight aggregated world regions (the Czech Republic, the rest of the 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) [10] .

3.1 The Social Planner Problem

Each region is endowed with an arable land $\mathcal{L}$, and populated by a representative agent. The representative agent consumes a final good C_{it}, food A_{it}, public good G_{it}, and supplies an inelastic amount of labor L_{it}. In each region, there is a social planner [11] who acts on behalf of the representative agent and solves following problem:

$$\max \mathcal{E}_0 \sum_{t=0}^{\infty} \beta^t u \left(C_{it}, G_{it}, A_{it} \right), \tag{1}$$

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[10] For exact division of the countries see Table 5

[11] The planner approach can be defended with the reference to the first welfare theorem, which states that the competitive allocation coincides with a planner allocation under certain circumstances (which are satisfied here). Negishi [33] shows that in CGE models it may be easier to solve the planner problem rather than to find the corresponding competitive allocation and this paper follows this approach.

where $\mathcal{E}_0$ is the expectation operator and β is the parameter of the intertemporal rate of substitution. In the formulae above, as well as in all subsequent formulae, the subindex i refers to regions, while the subindex t refers to time.

The planner maximizes (1) and respects the following set of constraints:

- the **GDP identity**:

  $$C_{it} + G_{it} + I_{it} + \phi(I_{it}, K_{it}) + I_{it}^o + \phi^o(I_{it}^o, K_{it}^o) + \varkappa(T_{it}) + X_{it} = Y_{it},$$

  where I_{it} are investments, K_{it} is the capital used in the final good sector, $\phi(I_{it}, K_{it})$ is the investment adjustment function, I_{it}^o and K_{it}^o are investments and capital used in the oil extracting sector with ϕ^o being the corresponding adjustment cost function (for regions, which do not produce oil, we set trivially $I_{it}^o = K_{it}^o = 0$), X_{it} are net exports of the final good, $\varkappa(T_{it})$ is the cost of using the backstop technology, and Y_{it} is the production of the final good;

- the **production function in the final-good sector**:

  $$Y_{it} = \mathbb{Y}(K_{it}, \zeta_{it} L_{it}^y, F_{it}),$$

  where $\mathbb{Y}$ is the neoclassical production function, L_{it}^y is the labor used in that sector, F_{it} is the fuel used in that sector, and ζ_{it} is the labor augmented technological progress;

- the **production function in the fuel-producing sector**:

  $$F_{it}^d = \mathbb{F}(O_{it}, \zeta_{it}^b B_{it}, \zeta_{it}^T T_{it}, L_{it}^f),$$

  where $\mathbb{F}$ is the production function, O_{it} are the conventional fossil fuels (henceforth referred to as oil) used for the production of fuel, B_{it} are the agricultural inputs, ζ_{it}^b is the technology progress, T_{it} is a back-stop technology and ζ_{it}^T is the corresponding technological progress, and F_{it}^d is the domestic production of fuels. The domestic production is related to the domestic consumption of fuels by the following identity:

  $$F_{it}^d = F_{it} + F_{it}^x,$$

  where F_{it}^x are net exports of fuels from region i. Similar identities hold for production, consumption and net exports of food and agricultural products used for biofuel production:

  $$A_{it}^d = A_{it} + A_{it}^x,$$

  $$B_{it}^d = B_{it} + B_{it}^x,$$

  where the d superscript denotes the domestic production, and the x superscript denotes net exports of the relevant variable.

- the **agricultural production function** reads as follows:

$$A^d_{it} + B^d_{it} = \mathbb{A}(L^a_{it}, \mathcal{L}_i, \zeta^a_{it}),$$

  where $\mathcal{L}_i$ is the agricultural land in region i, L^a_{it} is labor employed in agriculture, and ζ^a_{it} is the exogenous technological progress. The agricultural production function obviously requires that $\pi_{bt} \equiv \pi_{at}$.

- the **oil consumption** O_{it}, **oil production** O^d_{it}, and **oil net exports** O^x_{it} obey the following identities:

$$O_{it} = O^d_{it} - O^x_{it},$$

$$O^d_{it} = \chi(K^o_t, L^o_t, O^e_{it}),$$
$$R_{it+1} = R_{it} - O^e_{it} + \zeta^r_{it},$$

  where R_{it} are oil reserves, ζ^r_{it} are shocks to oil reserves (such as new discoveries). The function $\chi(K^o_t, L^o_t, O^e_{it})$ captures the notion that it is costly to extract the oil and that capital and labor should be used, we assume the sector-specific capital, i.e., the capital used in the oil extracting industry cannot be easily transferred to the final good sector[12]. The requirements on variables are $R_{it} \geq 0$, and for oil-nonproducing regions holds: $R_{it} \equiv 0$, $O^d_{it} \equiv 0$, $\zeta^r_{it} \equiv 0$, and thus $-O_{it} = O^x_{it} \leq 0$.

- The **balance of payments** reads as:

$$X_{it} + \pi_{at}B^x_{it} + \pi_{at}A^x_{it} + \pi_{ft}F^x_{it} + \pi_{ot}O^x_{it} + (1 + r_t)W_{it} = W_{it+1},$$

  where W_{it} is the net worth of region i, and π_{ft}, π_{at}, π_{ot} are relative prices of fuel, agricultural products, and oil respectively. Recall that $\pi_{at} = \pi_{bt}$ by virtue of the agricultural production function.

- The **capital accumulation** is standard one:

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

$$K^o_{it+1} = (1 - \delta_o)K^o_{it} + I^o_{it},$$

  where δ and δ_o are depreciation rates in the two sectors.

- The planner respects also the **labor-market clearing** conditions:

$$L_{it} = L^y_{it} + L^a_{it} + L^f_{it} + L^o_{it}.$$

There are multiple sectors in the economy: (i) the sector which produces the final good, which is both the consumption good as well as the investment good; (ii) the agricultural sector which produces food and biofuel inputs; (iii)

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[12] This assumptions is responsible of a sluggish adjustment of oil supply to its prices, a feature observed in reality.

the oil producing sector, which produces oil subject to crude oil reserves; this sector does not operate in each country, (iv) the fuel producing sectors which produces fuel from oil and from agricultural inputs, and (v) finally there is a back-stop technology, which has the potential to replace oil from producing fuels. The first four sectors are necessary ingredients in our model: the first sector is needed since it produces consumption and investment goods. The agricultural sector is needed to generate the biofuel-food trade-off (the land used for biofuel corps cannot be used for food production). The oil producing sector is necessary for (a) the model-consistent derivation of the oil price, since increased biofuel utilization can have effects on the oil price, on the investments in oil industry (hence affecting the future oil supply and future oil prices), and (b) modeling the trade effect and the cross-country distribution resulting from biofuel promotion (as biofuel policies may result in real transfers from oil producing countries to countries growing biofuel crops).

We include the backstop technology into the model for technical reasons only. Its only purpose is to have a well defined steady state, where the economy does not collapse to inaction due to the oil exhaustion[13]. Hovered, in our calibration, we always set productivity of the back stop technology very low in near future (so its utilization is negligible), and assume that it will substitute fossil fuels in very far future. By this we can impose a non-trivial model steady state without too much affecting the model results for near and medium terms.

3.2 The Functional Forms of Production Functions

The production functions are assumed to have the following functional form:

- The production function in the **final good sector** $\mathbb{Y}$ is assumed to have standard Cobb-Douglas form, where the shares are derived from the 'averages' observed in the economy.
- The production function in the **sector producing fuel** satisfies:

$$\mathbb{F}(O_{it}, \zeta^b_{it} B_{it}, L^f_{it}) = (\alpha_o {O_{it}^{-\rho}} + (1-\alpha_o) {B_{it}^{-\rho}})^{-\alpha_f/\rho} (L^f_{it})^{(1-\alpha_f)}.$$

The parameter $\rho \in (-1, 0)$ captures the notion that biofuels and fossil fuels

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[13] The reader may ask whether there exists a parametrization such that the economy can attain a non-decreasing path of production and consumption despite the continuous decline in oil supply. We can confirm that such a parameterizations indeed does exist – basically the share of fuel in the final good production function has to be low or the agriculture sector must be very productive. Then, it is possible to substitute fuels by capital or oil by biofuels. Nevertheless, such a property is not always satisfied and we do not want to ex-ante impose such a calibration on our model.

are substitutes ($\rho < 0$), although imperfect ($\rho > -1$). The labor share α_f is calibrated to replicate the labor costs in this industry. In this version of the model, we abstract from capital (according to the cost structure, its cost share of capital is much lower than that of fuels, oil, and labor).

- The production function in the **agricultural sector** is defined as follows:

$$\mathbb{A} = \zeta^a_{it}\mathcal{L}_i\left(L^a_{it}\right)^{\alpha_A},$$

  where ζ^a_{it} models the technological progress, $\mathcal{L}_i$ is the amount of arable land (assumed to be constant in this version of the model), and L^a_{it} is labor used in agriculture. The parameter α_A models decreasing returns to scale of labor. In this version of the model, we assume that the agricultural land is fixed. However, if an extension with variable land use were considered, the production function should change as this form would imply increasing returns to scale in agriculture[14]. Still, the fixed land assumption is reasonable if one wants to model policies constrained by 'sustainable' criteria currently being set on biofuels.

3.3 The Bellman Equation and Solution for an Oil-producing Region

In this section, we deliberately describe the Bellman's equation and solution for oil producing region. By setting some assumptions, reader may easily derive relevant equations for oil-nonprooducing region including, for example, the Czech Republic[15].

The Bellman's equation for **oil producers** reads as follows:

$$\begin{aligned}\mathcal{V}(K_{it}, K^o_{it}, W_{it}, R_{it}) = \max u\left(C_{it}, G_{it}, A_{it}|\xi_{it}\right) + \beta\mathcal{E}_t\mathcal{V}(K_{it+1}, K^o_{it+1}, W_{it+1}, R_{it+1})\\ -\lambda^f_t\left(F_{it} - F^x_{it} - \mathbb{F}(O_{it}, \zeta^b_{it}B_{it}, \zeta^T_{it}T_{it}, L^f_{it})\right)\\ -\lambda^a_t\left(A_{it} + B_{it} + \overline{A}^x_{it} - \mathbb{A}(L^a_{it}, \mathcal{L}_i, \zeta^a_{it})\right)\\ -\lambda^l_t\left(L_{it} - L^y_{it} - L^a_{it} - L^f_{it} - L^o_{it}\right) - v_{it}T_{it},\end{aligned}$$

where a new variable $\overline{A}^x_{it} = A^x_{it} + B^x_{it}$ has been created to lower the dimensionality of the problem. Also the GDP identity can be used to substitute the consumption from the problem. The variable λ^f_t is the Lagrange multiplier associated with the constraint given by the fuel production function, the Lagrange multiplier λ^a_t is associated with the agricultural sectors, λ^l_t is the Lagrange multiplier associated with the labor constraint, and v_{it} is the

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[14] We thank to Sergey Slobodyan for pointing us this issue.

[15] For oil non-producing regions we set $I^o_{it} = K^o_{it} = 0$, $R_{it} \equiv 0$, $O^d_{it} \equiv 0$, $\zeta^r_{it} \equiv 0$ and consequently $-O_{it} = O^x_{it} \leq 0$.

Kuhn-Tucker multiplier related to the backstop technology[16]. The resource constraint $R_{it} = R_{it+1} - O^e_{it} + \zeta^r_{it}$ enters directly the value function. We also eliminate O^d_{it} by $O_{it} = O^d_{it} - O^x_{it} = \chi(K^o_t, L^o_t, O^e_{it}) - O^x_{it}$ and optimize with respect to O^e_{it} and O^x_{it} only.

The condition $\lambda^f_t \mathbb{F}_{Ot} = \beta \mathcal{E}_t \mathcal{V}_{Rt+1}$ with $u_{ct} = \beta \mathcal{E}_t \mathcal{V}_{Wt+1}$ and with $\pi_{ot} \beta \mathcal{E}_t \mathcal{V}_{Wt+1} = \beta \mathcal{E}_t \mathcal{V}_{Rt+1}$ yield a familiar equality of marginal product with prices $\pi_{ft} \mathbb{F}_{Ot} = \pi_{ot}$. The inter-temporal Euler equation with the envelope condition dictate the generalization of the Hotteling rule[17]:

$$\pi_{ot} u_{ct} \chi_{Ot} = \beta \mathcal{E}_t u_{ct+1} \pi_{ot+1} \chi_{Ot+1}$$

After some simple algebraic manipulation with the first oder conditions[18], we get the solution in the following form:

$$\begin{aligned} u_{ct} = u_{gt} &= u_{at}/\pi_{at}, \\ \mathbb{Y}_{F_t} &= \pi_{ft}, \\ \mathbb{Y}_{Lt} = \pi_{at} \mathbb{A}_{Lt} = \pi_{ft} \mathbb{F}_{Lt} &= \pi_{ft} \mathbb{F}_{ot} \chi_{Lt}, \\ \pi_{ft} \mathbb{F}_{Bt} &= \pi_{at}, \\ \pi_{ft} \mathbb{F}_{Ot} &= \pi_{ot}, \end{aligned}$$

The interpretation of these equations is straightforward. First equation equalize marginal utility of private consumption with marginal utility of public consumption (famous Samuelson condition) and also with marginal utility of consumption of agricultural good evaluated by its price[19]. The second equation equals marginal product of fuel to its price. The third equation equalize marginal productivities of labour in selected sectors. Fourth and fifth equation show that marginal product of biofuels (agricultural products) and crude oil equals to their prices.

Moreover the Euler equation of the problem equalizes marginal utility of private consumption in two time periods:

$$u_{ct} = \beta \mathcal{E}_t (1 + r_{t+1}) u_{ct+1}$$

The higher the interest rate in next period, the more would consumer like to invest in current period (causing an increase in marginal utility of current

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[16] I.e., $v_{it} = 0$ if the technology is used in year t and $v_{it} > 0$ if it is not.

[17] If the oil were extracted costlessly, this equation would imply the standard Hotteling rule ($\pi_{ot} = \beta \mathcal{E}_t \frac{u_{ct+1}}{u_{ct}} \pi_{ot+1}$), which dictates that the price of an exhaustible asset should growth at the rate of intertemporal substitution.

[18] Here we transform shadow prices λ^a_t, λ^f_t, λ^o_t into real monetary units using the following relation: $u_{ct} = \lambda^a_t/\pi_{at} = \lambda^f_t/\pi_{ft}$.

[19] This is because $\pi_{ct} \equiv \pi_{gt} \equiv 1$

consumption). On the other hand the increase in consumption in the next period causes decrease in marginal utility of consumption. Finally, we also get the equation of the inter-temporal allocation of capital:

$$u_{ct}(1+\phi_{It}) = \beta \mathcal{E}_t u_{ct+1} \left[\mathbb{Y}_{Kt+1} + \phi_{Kt} - (1-\delta)(1+\phi_{It+1}) \right].$$

3.4 The closure of the model

To close the model, the rest of equilibrium conditions have to be specified. Mainly, the sum of world net exports should be zero:

$$\begin{aligned} \sum_{i\in\mathcal{I}} X_{it} &= 0, \\ \sum_{i\in\mathcal{I}} \overline{A}^x_{it} &= 0, \\ \sum_{i\in\mathcal{I}} F^x_{it} &= 0, \\ \sum_{i\in\mathcal{I}} O^x_{it} &= 0. \end{aligned}$$

These equations will determine the international relative prices π_{at}, π_{ft}, π_{ot} and the world interest rate r_t. By virtue of the Walras law, also $\sum_{i\in\mathcal{I}} [W_{it+1} - (1+r_t)W_{it}] = 0$.

3.5 Calibration of the Model

Up to now, the model has been calibrated to reflect:

- average shares of food in consumption are used for calibration of the parameters of the utility function u;
- the parameters of the utility function u related to the government spending are calibrated from national account to mimic the ratio of government spending on GDP;
- the cost structure in relevant industries is utilized for calibration of the parameters of the production functions;
- the data on international trade in oil and agricultural products replicates the trade balances;
- the parameter β is calibrated to the conventional value in literature (0.95).

4 An Illustrative Simulation

The core version of the model was applied for simulation of the impact of growing world oil prices. Figure 1 reports the long-run (steady state) effects of oil price changes on the Czech variables. On the x-axis there is assumed percentage change in the oil price (normalized initially at 100%) and on the y-axis there is an implied long-run change in selected variables.

It can be seen that growing world price of crude oil causes a reduction of crude oil imports. The response is relatively high and will be subject to further revisions of calibration. On the other hand, the negative response of crude oil imports and consequently traditional fossil fuel production leads to penetration of biofuels on the market. This can be seen in the upper right corner graph where consumption of biofuels increases with the growing price of crude oil. Again, the response is relatively high and will be subject to revisions. Nevertheless, the expected relationship is seen, ie. the crude oil dependency decreases with crude oil prices while the biofuels substitute fossil fuels. It can also be seen that agricultural products needed for production of biofuels are being obtained from abroad. Simultaneously, previously exported agricultural production is used for domestic production of biofuels - therefore net exports of agricultural goods are decreasing with increasing price of crude oil. The increase in imports can be explained by the fact that the similar effect applies in other regions and the biofuel production is boosted worldwide, but relatively more in less developed regions, which are now willing to serve the demand in the developed regions including Czech Republic. Still, even the domestic agricultural production boosts due to price incentives. We also see a slight increase in domestic agricultural employment[20].

5 Conclusion

We introduced the description of the world model that is assumed to evaluate impacts of biofuel promotional policies in the world on the Czech economy. Because of the nature of biofuel market and biofuel production/use chain, the multiregional dynamic general equilibrium model has been chosen for the analysis. The need for proper incorporation of dynamic features and also due to the data availability our model assumes restricted homogeneous land area as input into agricultural production. However, the model underpins competition between biofuels and food on restricted land area with consequent impact on prices of agricultural commodities. Currently, the static version of the CGE model has been calibrated and applied for initial simulations. The simulations

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[20] It can be stressed that the simulation were run with simple core of the model.

are gradually being improved but there still exists an area for further improvements and extensions. Nevertheless, we investigated the effect of changes of crude oil prices on the main variables in the model. The model results imply that growing crude oil price causes a decrease in crude oil imports, increase in domestic consumption of biofuels, with moderate favor impact on domestic agricultural production and agricultural employment. In order to evaluate impacts of biofuels promotional measures, the model has to be further enriched. It is planned to extend it by the existence of two types of households, at least for the case of the Czech Republic. In this case, the social planner approach has to be left. The types of households will address the need for more comprehensive analysis of impacts on agricultural households (and regions). The associated extension consists of introduction of distortionary taxes like labor taxes, profit tax, VAT and excise tax.

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Table 1: Division of the world.

Region	**Countries**
Czech Republic	Czech Republic
EU 26	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
rest OECD	Australia, Canada, Switzerland, Iceland, Japan, Korea, Mexico, Norway, New Zealand, Turkey, United States
OPEC countries	Angola, United Arab Emirates, Algeria, Ecuador, Iran, Iraq, Kuwait, Lybia, Nigeria, Quatar, Saudi Arabia, Venezuela
former USSR	Azerbaian, Belarus, Georgia, Kazakhstan, Russia, Ukraine, Uzbekistan
rest Asia	Bangladesh, China, Hong Kong, Indonesia, India, Lebanon, Sri Lanka, Malaysia, Oman, Pakistan, Philippines, Singapore, Syrian Arab Republic, Thailand, Vietnam, Yemen
Latin America	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Guatemala, Honduras, Jamaica, Panama, Peru, Puerto Rico, Paraguay, El Salvador, Uruguay
rest Africa	Botswana, Cote d'Ivore, Cameroon, Egypt, Ethiopia, Kenya, Morocco, Sudan, Tunisia, Tanzania, South Africa, Congo, Zambia, Zimbabwe

Fig. 1. Simulation results