Distributional effects of biofuel promotion policies in a transition country

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Abstract

This paper evaluates the impact of selected biofuel promotion policies in a transition country – the Czech Republic. To do that, the paper introduces a dynamic CGE model with three features. First, the model assumes heterogenous households and therefore it can analyze distributional effects of policy measures. Second, the model has a detailed agricultural sector to address the competition between biofuel feedstock and food production for arable land. Third, the model contains features specific for transition economies, such as real convergence, which affect the dynamics of relative prices. Therefore, the model is able to generate realistic scenarios and simulate them.

In this paper, we simulate and compare alternative approaches to achieving the 10% target as dictated by the Directive 2009/28/EC. We consider a gradual introduction of subsidies for biofuel feedstock products so that the target is achieved by 2020. Our results suggest that if the subsidy is financed by the increase in labor taxes, the policy would not only cause economic distortion, but it may hurt the agricultural sector even relatively more. If the subsidy is financed by the increase in excise tax on motor fuels, then the distortions are alleviated and the agricultural sector may benefit from the policy measure. This shows that it is not irrelevant how the target is achieved.

Key words: Biofuels; Agricultural sector; CGE modeling
J.E.L. Classification: C68, Q18, Q42.

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1 Introduction

The production and consumption of various types of bioenergy has gradually become an important global issue in the last decade. Recently, the policymakers around the world, driven by the idea of reduction of greenhouse gases (GHG) emissions, have started to pay attention to this topic. Since the transport sector produces around 30 % of total GHG emissions, the biofuels play crucial role in the policy debates related to bioenergies. Together with their potential in the reduction of GHG, the mostly cited associated advantages of promotion of biofuels are creation of alternative outlets for farmers' production, a consequent increase in farm income, and development of rural areas. Another advantage is associated with weakening of the dependency on fossil fuel sources imported from politically instable regions; Wiesenthal et al (2009).

Based on the above mentioned arguments, the vast majority of leading world countries announced their aims in substitution of traditional fuels by biofuels (OECD, 2008). The European Union, for example, declared to reach the 10 % target in the transport sector by the year 2020. The goal is currently incorporated in the Directive of European Parliament and Council no. 2009/28/EC on the promotion of the use of energy from renewable sources.

There have, however, appeared voices accusing biofuels of bringing about adverse environmental and economic consequences [1] . Even the effects on overall employment and farmers' income also deserve a deeper discussions. In the case of employment, Edwards et. al. (2008) summarizes different aspects that affect resulting employment impact in whole economy. The various doubts about the influence on farm describe Rajagopal and Zilberman (2007).

There exist numerous approaches to evaluation of economic implications of biofuel promotion measures. The nature of the biofuel market, its gradually tighter links with the energy market and its interconnections with other sectors in the economy predetermines computable general equilibrium (CGE) models to be an useful tool for such type of analyses. Indeed, it has been applied variety of CGE approaches to modeling economic impacts of biofuel supporting policies. The models differ, for example, by addressing the land use issue, the regional coverage or dynamic features that are incorporated into the model [2] .

[1] For example, Mellilo et. al. (2009), Searchinger et. al. (2008), or Fargione et. al. (2008) discuss negative effects on land use change and the environment that result from a biofuel boom. Regarding ambiguous economic repercussions, Doornbosch and Steenblik (2007), Mitchell (2008), or Eide (2008), for example, express strong concerns about influence of biofuel promotional policies on increases in food prices. Namely, rising food prices can imply negative unintended effects in society since the poorer households / countries are more severely affected by higher prices of food.

[2] Dixon et. al. (2007) assume homogeneous land as factor of production and apply

The majority of models have been applied either to advanced countries and these models typically evaluate the effects of policy measures, or to developing countries and then the models tend to address the effects of land use competition on food prices and their consequences for poor. There has been, however, little research on European transition countries so far. This is an unfortunate gap as these countries are obliged to fulfill relevant Directives of the European Commission.

To address this gap, this paper presents a CGE model calibrated for a transitional economy – the Czech Republic. The model is characterized with three features. First, the model assumes heterogenous households (agricultural and non-agricultural households). Therefore, the model is able to analyze different impacts of policy measures on the two types of households. Second, the model has a detailed agricultural sector to address the competition between biofuel feedstock and food production for arable land. Third, the model contains features specific for the transition economies in Central Europe. This is important since the real convergence in transition economies in Central Europe is characterized by permanent changes in real prices and real exchange rate appreciation (see Andrle et al, 2009, for evidence). As these features permanently affects relative price, they have non-trivial effects on the dynamics of these economies. Real exchange rate appreciation, for example, lowers the relative prices of imported commodities such as oil or food and at the same time increases the relative price of exports. Interestingly, this increase in export prices has not threatened the exporting performance of the Central European countries, as documented and explained by Brůha and Podpiera (2011). That means that these economies can trade the domestic production for imported foreign goods (including commodities) in more favorable terms. Therefore, the usual static CGE model would not be sufficient to consistently capture the reaction of the economic agents to shocks or policy measures in time.

In this paper, we use the model to assess the impacts of the 10% target as is

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the economic model USAGE for evaluation of mandatory blending quotas in the U.S. economy. Similarly, Kretchmer et. al. (2009) incorporate biofuel issue into the DART model and assess economic impacts of 10 % biofuel target in the EU. Furthermore, several studies incorporate a constant elasticity of transformation (CET) function allowing landowners for choosing optimal utilization of their restricted land area according to its yield and usage. Such approach is used, among other, by Hertel and Tsigas (1998) who analyze effects of the elimination of the farm and food tax preferences on the US economy. Banse et. al. (2008) use more elaborated system of constant elasticity transformation functions that take an 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. Kahrl and Roland-Holst (2010) use a static general equilibrium approach in estimation of welfare effects and show how energy and food prices interact to affect household income and cost of living in Senegal.

dictated by the Directive 2009/28/EC. The rest of the paper is organized as follows. The next section 2 describes the model used for simulations. Section 3 describes the simulated scenario with the explanation of the results. The last section 4 concludes.

2 Model

This paper presents a model of a converging small open economy. The country is endowed with an arable land $\mathcal{L}$ and is populated by two representative agents: agricultural and non-agricultural households. The economy is divided into four main sectors: intermediate good sector (this sector produces most of the national value added), final good sector, motor fuel sector, and agricultural sector producing either food or biofuel feedstock.

All prices are – as is usual in CGE models – real. We normalize the price of the intermediate good sector to unity and all other prices (including wages and profits) are expressed in terms of this price.

The time is discrete and the basic unit is one year.

2.1 Households

There are two types of households in the economy: the agricultural and the non-agricultural household. Both representative agents consume the final consumption good, food, motor fuels, and supplies an elastic amount of labor. Both households invest to the physical capital (agricultural households to the physical capital used in the agricultural sector, why the other household to the capital used in the intermediate good sector). The physical capital is internationally immobile and is immobile also across sectors. This is a realistic feature for modeling sluggish adjustments of real economy to changes in relative prices. The non-agricultural households can also invest to the internationally traded bonds, while the agricultural households receive the income from land.

2.1.1 Non-agricultural Household

The non-agricultural household enjoys the private consumption of non-food products C_{ht}, the consumption of food A_{ht}, the consumption of motor fuels F_{ht}, and dislikes the work effort L_{ht}. He maximizes the expected discounted sum of momentary utilities u over the infinite horizon:

$$\max \sum_{t=0}^{\infty} \beta^t u\left(C_{ht}, A_{ht}, F_{ht}, L_{ht}\right), \tag{1}$$

subject to the budget constraint:

$$\begin{aligned} &\pi_t^{cf} C_{ht}\left(1+\tau_t^{vat}\right)+\pi_t^{af} A_{ht}\left(1+\tau_t^{vatA}\right)+\left(\pi_t^{f}+\tau_{it}^{ex}\right) F_{ht}\left(1+\tau_t^{vat}\right)+\pi_t^{if}\left[I_{ht}+\phi\left(I_{ht}, K_{ht}\right)\right] \leq \\ &\quad \leq w_{ht} L_{ht}\left(1-\tau_t^{l}\right)+\Pi_{ht}\left(1-\tau_t^{p}\right)+\eta_t\left[\left(1+r_t\right) W_{h,t}-W_{h,t+1}\right], \end{aligned} \tag{2}$$

and subject to the capital accumulation:

$$K_{h,t+1}=(1-\delta) K_{h,t}+I_{h,t}, \tag{3}$$

where π_t^{cf} is the real price of the consumption good [3], π_t^{af} is the real consumer food price, π_t^{f} is the domestic before-tax price of motor fuels [4], π_t^{if} is the real price of the investment good, $W_{h,t}$ is the net wealth held by the household, r_t is the corresponding real interest rate (determined exogenously in the rest of the world), η_t is the real exchange rate, $K_{h,t}$ is the physical capital stock used in the intermediate sector, $I_{h,t}$ are corresponding investments, w_{ht} is the real wage rate, and Π_{ht} is profit realized in the intermediate good sector. The parameter $\beta \in (0;1)$ represents the inter-temporal rate of substitution, and $\phi\left(I_{ht}, K_{ht}\right)$ adjustment cost function for physical capital. The tax-policy parameters are following: τ_t^{vat} represents standard value added tax, τ_t^{vatA} is the value added tax rate levied on food (which differs from the standard VAT rate in the Czech Republic), the profit tax rate τ_t^{p}, and the labor tax rate τ_t^{l}.

The momentary utility function is assumed to have the following form (i.e., the Garry-Stone utility function):

$$u=\ln C_{i,t}^{h}+\xi_{ha} \ln \left(A_{i,t}^{h}-\bar{A}\right)+\xi_{hf} \ln \left(F_{i,t}^{h}-\overline{F}\right)-\xi_{hl} \frac{1}{\phi_h}\left(L_{i,t}^{h}\right)^{\phi_h},$$

where ξ_{ha} and ξ_{hf} are parameters determining expenditure shares and which are calibrated based on the Czech Household Budget Survey. The parameters $\bar{A}$ and $\overline{F}$ allow the demand to be non-homotetic [5]. ϕ_h is the elasticity of labor supply and is calibrated to the conventional value 2. Cost adjustment function is assumed to be: $\phi\left(I_{ht}, K_{ht}\right)=\frac{\varphi}{2}\left(\frac{I_{ht}}{K_{ht}}-\delta\right)^2 K_{ht}$, with $\varphi \geq 0$. Household's

[3] See Equation (16) below for definition and discussion of this price.

[4] This price is related to the world price $\tilde{\pi}_t^{f}$ as follows: $\pi_t^{f}=\eta_t \tilde{\pi}_t^{f}$, where η is the real exchange rate. Henceforth, all exogenous world prices will be denoted by tilde sign.

[5] In fact, $\bar{A}>0$ means that the expenditure share on food is decreasing in total expenditures and $\bar{F}<0$ means that motor fuel is a luxury good.

optimization implies the following optimality conditions:

$$\pi_t^{cf} C_{ht} \left(1 + \tau_t^{vat}\right) = \frac{1}{\xi_{ha}} \left(A_{ht} - \bar{A}\right) \pi_t^{ca} \left(1 + \tau_t^{vatA}\right), \tag{4}$$

$$\pi_t^{cf} C_{ht} = \frac{1}{\xi_{hf}} \left(F_{ht} - \overline{F}\right) \left(\pi_t^f + \tau_t^{ex}\right), \tag{5}$$

$$C_{ht} \left(1 + \tau_t^{vat}\right) = \frac{1}{\xi_{hl}} \left(L_{ht}\right)^{1-\phi_h} w_{ht} \left(1 - \tau_t^l\right), \tag{6}$$

$$C_{ht+1} \left(1 + \tau_{t+1}^{vat}\right) = \beta C_{ht} \left(1 + \tau_t^{vat}\right) \left(1 + r_{t+1}\right), \tag{7}$$

$$1 + \varphi \left(\frac{I_{ht}}{K_{ht}} - \delta\right) = \tag{8}$$

$$= \frac{1}{1 + r_{t+1}} \left[\frac{\partial \Pi_{ht}}{\partial K_{h,t+1}} \left(1 - \tau_{t+1}^p\right) - \frac{\varphi}{2} \left(\delta^2 - \frac{I_{h,t+1}^2}{K_{h,t+1}^2}\right) + (1 - \delta) \left(1 + \varphi \left(\frac{I_{hi,t+1}}{K_{h,t+1}} - \delta\right)\right)\right],$$

where (4) is the optimal demand for food, (5) is the optimal demand for motor fuels, (6) is the labor supply, (7) is the consumption Euler equation, and Equation (8) determines the optimal investments as a function of the expected after-tax marginal return on capital $\frac{\partial \Pi_{ht}}{\partial K_{h,t+1}} \left(1 - \tau_{t+1}^p\right)$, and current and expected adjustment costs.

2.1.2 *Agricultural Household*

The agricultural household maximizes a similar utility function as the other household, however we assume that she does not accumulate financial wealth. She maximizes:

$$\max \sum_{t=0}^{\infty} \beta^t u \left(C_{at}, A_{at}, F_{at}, L_{at}\right), \tag{9}$$

subject to the budget constraint:

$$\pi_t^{cf} C_{at} \left(1 + \tau_t^{vat}\right) + \pi_t^{af} A_{at} \left(1 + \tau_t^{vatA}\right) + \left(\pi_t^f + \tau_{it}^{ex}\right) F_{at} \left(1 + \tau_t^{vat}\right) + \pi_t^{if} \left[I_{at} + \phi \left(I_{at}, K_{at}\right)\right] \leq \tag{10}$$

$$\leq w_{at} L_{at} \left(1 - \tau_t^l\right) + \Pi_{at} \left(1 - \tau_t^p\right) + \pi_t^l \mathcal{L},$$

and subject to the capital accumulation in the agriculture sector:

$$K_{a,t+1} = (1 - \delta) K_{a,t} + I_{a,t}. \tag{11}$$

where C_{at} is consumption of the final consumption good by the agricultural household, A_{at} is her consumption of food, L_{at} is the labor supplied to the agricultural sector, w_{at} is the corresponding real wage, K_{at} is the physical capital employed in the agricultural sector, I_{at} are corresponding investments, $\phi \left(I_{at}, K_{at}\right)$ adjustment costs, Π_{at} is the profit in the sector, and π_t^l is the rental rate for land $\mathcal{L}$..

The first order conditions, which determine the demand for food, fuel, labor supply, and investment to the physical capital, are analogous to the case of non-agriculture households and therefore are not repeated here.

2.2 Firms

2.2.1 Intermediate Good Sector

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

$$\max \mathbb{Y}\left(K_{ht}, \zeta_{yt} L_{yt}, F_{yt}\right) - w_{ht} L_{yt} - F_{y,t}\left(\pi_t^f + \tau_t^{ex}\right), \tag{12}$$

where $\mathbb{Y}$ is intermediate good production function, $F_{y,t}$ are motor fuels consumed in this sector, L_{yt} is the labor employed in production of the intermediate good (and in equilibrium equal to L_{ht}), w_{ht} is the real wage, ζ_{yt} is the labor augmented technological change, π_t^f is the domestic price of motor fuels, and τ_t^{ex} stands for excise fuel taxe [6].

The production function is assumed to be given as a Cobb-Douglas production function $\mathbb{Y}_t = K_{ht}^{\alpha_{Ky}} \left(\zeta_{yt} L_{yt}\right)^{\alpha_{ly}} F_{y,t}^{1-\alpha_{ly}-\alpha_{Ky}}$ and the standard cost minimization implies the following formulae:

$$\alpha_{ly} \mathbb{Y}_t = w_{ht} L_{yt}, \tag{13}$$

$$\left(1 - \alpha_{Ky} - \alpha_{ly}\right) \mathbb{Y}_t = F_{y,t}\left(\pi_t^f + \tau_t^{ex}\right), \tag{14}$$

$$\Pi_{ht} = \mathbb{Y}_t - w_{ht} L_{yt} - F_{y,t}\left(\pi_t^f + \tau_t^{ex}\right) = \alpha_{ky} \mathbb{Y}_t. \tag{15}$$

The marginal return on capital is therefore given as $\frac{\partial \Pi_{ht}}{\partial K_{h,t+1}} = \alpha_{ky} \frac{\mathbb{Y}_t}{K_{h,t+1}}$. Notice that we assume that all labor taxes are paid by households and not by firms. This is – in the neoclassical framework – a completely innocent assumption, as labor taxes create the same wedge between the marginal product of labor and the marginal rate of substitution regardless whether they are paid by firms or workers. From the calibration perspective, this means that the household labor tax rate in this model also includes the obligatory social and health security payments.

[6] Note that this is a *unit tax* rather than an *ad valorem tax.*

2.2.2 Final good sector

The intermediate production $\mathbb{Y}_t$ is then combined with imports to create main GDP components: consumption good $\mathbb{C}_t$, investment good $\mathbb{J}_t$, government consumption good $\mathbb{G}_t$, and export goods $\mathbb{X}_t$ using a CES aggregators. This feature is taken from Andrle et al (2009) and Tonner et al (2011) and is motivated by several empirical facts of the Czech economy: investments are very import dependent, as well as exports are. This assumption also enables to replicate the permanent divergence among relative prices of various GDP components.

To exemplify this approach, let us consider the composition of the final consumption good. This good is produced as:

$$\mathbb{C}_t = \left[\alpha_C \mathbb{Y}_{ct}^{-\varrho_C} + (1-\alpha_C)\mathbb{M}_{ct}^{-\varrho_C}\right]^{\frac{-1}{\rho_C}},$$

where $\rho_C \geq -1$ is the elasticity of substitution, α_C is the expenditure share, $\mathbb{Y}_{ct}$ is the domestic component of consumption, and $\mathbb{M}_{ct}$ is the imported component of consumption. The cost minimization implies the following expression for the real consumption deflator (i.e, for the before-tax consumer price of the consumption good)[7]:

$$\pi_t^{cf} = \begin{cases} \left[\alpha_C^{\frac{1}{1+\varrho_C}} + (1-\alpha_C)^{\frac{1}{1+\rho_C}}\eta_t^{\frac{\rho_C}{1+\rho_C}}\right]^{\frac{1+\rho_C}{\rho_C}} & \text{if} \quad \rho_C \neq 0, -1 \\ \alpha_C + (1-\alpha_C)\eta_t & \text{if} \quad \rho_C = -1 \\ \eta_t^{1-\alpha_C} & \text{if} \quad \rho_C = 0 \end{cases}, \tag{16}$$

Imperfect substitution implies that η_t may deviate from unity. If $\rho_C \to \infty$ (i.e., if the domestic and imported goods were perfect substitutes), then $\eta_t = 1$, as well as $\pi_t^{cf} = 1$.

The similar formulae apply for the rest of the GDP components as well and therefore we get the definitions of $\mathbb{J}_t$, $\mathbb{G}_t$, $\mathbb{X}_t$, and of π_t^{if}, π_t^{gf}, π_t^{xf}. The fact that shares in the CES functions may be different means that different deflators react differently to movements in the exchange rate. This is observed regularity for the Czech Republic. The calibration of these shares are taken from[8] Andrle

[7] Recall that η_t is the real exchange rate and that the price of $\mathbb{Y}_t$(and hence of $\mathbb{Y}_{ct}$) is normalized to one.

[8] With following exceptions: first, Andrle et al (2009) assume that $\alpha_J = 0$, i.e., that investments are 100% imported. We take here $\alpha_J = 0.25$, which means that investments are heavily dependent on imports, but there is a non-negligible domestic component. Another difference is that Andrle et al (2009) assume $\rho_c = \rho_J = \rho_G = \rho_x = -1$, (i.e., fixed proportions of domestic and imported components), which is probably realistic for a quarterly model. We, however, calibrate $\rho_c = \rho_J = \rho_G =$

et al (2009).

The market clearing for the intermediate good then reads as [9]:

$$\mathbb{Y}_t = \mathbb{Y}_{ct} + \mathbb{Y}_{jt} + \mathbb{Y}_{gt} + \mathbb{Y}_{xt}, \tag{17}$$

and the imports for the GDP components are given as [10]:

$$\mathbb{M}_t = \mathbb{M}_{ct} + \mathbb{M}_{jt} + \mathbb{M}_{gt} + \mathbb{M}_{xt}. \tag{18}$$

Note that $\mathbb{M}_t$ is not the total imports, as the economy imports also other commodities, such as oil, and (at least partly) food.

The demand for the exports is given by the following export function:

$$\mathbb{X}_t = \zeta_{xt} e^{\xi_x(\eta_t - 1)},$$

where ζ_{xt} is the time-varying level of exports in the situation of $\eta_t = 1$, and ξ_x captures the demand elasticity. The time varying nature of ζ_{xt} is needed to replicate the increasing openness of the Czech economy (see Andrle et al, 2009, or Brůha et al., 2010, for evidence) .

2.2.3 Fuel Producing Sector

The sector producing fuels uses for its production crude oil and biofuel feedstock as an alternative input. The maximization problem can be read as follows:

$$\max \pi_t^f \mathbb{F}^d \left(O_t, \zeta_{bt} B_t\right) - \pi_t^o O_t - \pi_t^b B_t, \tag{19}$$

where $\mathbb{F}^d$ is production function in fuel sector, π_t^f is the domestic fuel price, O_t is crude oil used for production of motor fuels (oil is imported), B_t is biofuel feedstock used for production of motor fuels, ζ_{bt} is the technological improvement in used of biofuel feedstock, and π_t^o is the the price of imported oil, which is related to the world price of crude oil $\tilde{\pi}_t^o$ as $\pi_t^o = \eta_t \tilde{\pi}_t^o$. The production function is assumed to have the CES form:

$$\mathbb{F}_{i,t}^d = \left[\left(\alpha_o O_t^{-\rho_f} + (1-\alpha_o)\,\zeta_{bt} B_t^{-\rho_f}\right)\right]^{-\frac{1}{\rho_f}}$$

$\rho_x = -0.5$, and thus allow for substitution between these two components. This is more plausible for our yearly model.

[9] $\mathbb{Y}_{ct}$, $\mathbb{Y}_{jt}$, $\mathbb{Y}_{gt}$, $\mathbb{Y}_{xt}$ are domestic components of consumption good, investment good, government good, and exports respectively.

[10] $\mathbb{M}_{ct}$, $\mathbb{M}_{jt}$, $\mathbb{M}_{gt}$, $\mathbb{M}_{xt}$ are imported components of consumption good, investment good, government good, and exports respectively.

and the first-order conditions imply:

$$\pi_t^o O_t^{1+\rho_f} = \pi_t^f \alpha_o \left(\mathbb{F}_t^d\right)^{1+\rho_f}, \tag{20}$$

$$\pi_t^b B_t^{1+\rho_f} = \pi_t^f (1-\alpha_o)\zeta_{bt} \left(\mathbb{F}_t^d\right)^{1+\rho_f}. \tag{21}$$

2.2.4 Domestic Agricultural Sector

The agricultural sector is relatively complex in this model. There are several stages of the agriculture and food production; see Figure 1. First, there is a basic sector, which produces raw agriculture products $\mathbb{A}_t^z$, price of which is π_t^{az}. This production is divided by the constant-elasticity-of-transformation (CET) function between biofuel feedstock B_t and the intermediate agriculture production A_t^i, the price of which is π_t^{ai}. This intermediate production A_t^i is then divided between agriculture product exports A_t^x (which are sold at the world exogenous price [11] $\tilde{\pi}_t^{a*}$) and the domestic component A_t^{id}. This division follows another CET function [12]. The domestic component is then combined with imported agricultural products (with the world price again $\tilde{\pi}_t^{a*}$) using a CES function to create the final agriculture good (food) consumed by households. The quantity of this good is denoted as $\mathbb{A}_{it}^d$ and its price as π_t^{af}. The reason for the complicated structure is the need to model (i) the competition between various uses of raw agricultural production (i.e., for biofuel feedstock, for exports, and for domestic use) and (ii) the imported component of the domestic food. Now, the stages of food production will be described in more details.

The raw agriculture production is produced using sector-specific capital, labor, land, and motor fuels. Therefore, the agricultural sector problem can be stated as follows:

$$\max \pi_t^{az} \mathbb{A}\left(K_{at}, \zeta_{at} L_{at}, \mathcal{L}, F_{zt}\right) - w_{at} L_{at} - \pi_t^l \mathcal{L} - F_{zt}\left(\pi_t^f + \tau_{at}^{ex}\right), \tag{22}$$

where π_t^{az} is the price of the raw agriculture output, ζ_{at} is the technological progress in agriculture, K_{at} is the capital, L_{at} is the labor used in the agriculture (equal to the labor supply be the agricultural household), $\mathcal{L}$ is the fixed amount of the arable land, π_t^l is the rental rate of land, F_{zt} are motor fuels used in the agriculture, τ_{at}^{ex} is the special excise tax rate for this sector [13].

[11] According to our convention, $\tilde{\pi}_t^{a*}$ is the price in the foreign currency, while the domestic price is given as $\eta_t \pi_t^{a*}$.

[12] This nested CET structure is needed as we do not want to allow for the same elasticity of transformation between biofuel feedstock, exported agricultural products and the part of production used domestically.

[13] In the Czech Republic, the budget pays back a part of the excise tax paid on fuels if the fuel is used in the agriculture. One way of modeling this instrument is

We assume that the production function is Cobb-Douglas, with the following form:

$$\mathbb{A}_t^z = K_{at}^{\alpha_{Ka}} \left(\zeta_{at} L_{at}\right)^{\alpha_{la}} \mathcal{L}^{\alpha_{LAND}} F_{zt}^{1-\alpha_{KA}-\alpha_{La}-\alpha_{LAND}}.$$

The cost minimization implies the following equations:

$$\pi_t^l \mathcal{L} = \alpha_{LAND} \pi_t^z \mathbb{A}_t^z, \tag{23}$$

$$w_{at} L_{at} = \alpha_{la} \pi_t^z \mathbb{A}_t^z, \tag{24}$$

$$\left(1 - \alpha_{ka} - \alpha_{la} - \alpha_{LAND}\right) \mathbb{A}_t^z = F_{zt} \left(\pi_t^f + \tau_{at}^{ex}\right). \tag{25}$$

and hence the before tax profit is given as:

$$\Pi_{at} = \mathbb{A}_t^z - w_{at} L_{at} - F_{zt} \left(\pi_t^f + \tau_{at}^{ex}\right) - \pi_t^l \mathcal{L} = \alpha_{ka} \mathbb{A}_t^z.$$

Since the land is in the fixed supply, this determines the rental rate π_t^l.

The CET assumption of the second stage means that the raw agricultural production is divided into the two outputs (biofuel feedstock and the agricultural intermediate products) based on the price ratio, i.e., the fraction of the output used for intermediate products is given by $\alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T}$, where $\left(1 + \tau_t^{sub}\right)$ is the subsidy for biofuel feedstock producers, and $\alpha_T \in (0, 1)$ with $\varrho_T > -1$ are parameters of the CET function. In the other words:

$$B_t = \frac{1}{1 + \alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T}} \mathbb{A}_t^z,$$

$$A_t^i = \frac{\alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T}}{1 + \alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T}} \mathbb{A}_{it}^z.$$

This also implies (under perfect competition) the following price equation:

$$\pi_t^{az} = \frac{\pi_t^{a,i} \alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T} + \pi_t^b \left(1 + \tau_t^{sub}\right)}{1 + \alpha_T \left(\frac{\pi_t^{a,i}}{\pi_t^b\left(1+\tau_t^{sub}\right)}\right)^{1+\varrho_T}}.$$

The third stage involves another CET function, which divides the intermediate agriculture products between exports A_t^x and the part used domestically $A_t^{i,d}$.

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to introduce a special rate τ_{at}^{ex}, which is lower than the standard rate.

Agriculture exports face the price π_t^{a*}. The CET function implies

$$A_t^x = \frac{1}{1+\alpha_X\left(\frac{\pi_{i,t}^{a,i}}{\pi_t^{a*}}\right)^{1+\varrho_x}} A_{i,t}^i,$$

$$A_t^{i,d} = \frac{\alpha_X\left(\frac{\pi_{i,t}^{a,i}}{\pi_t^{a*}}\right)^{1+\varrho_x}}{1+\alpha_X\left(\frac{\pi_{i,t}^{a,i}}{\pi_t^{a*}}\right)^{1+\varrho_x}} A_{i,t}^i.$$

The domestic intermediate products $A_t^{i,d}$ are finally combined with foreign imported agricultural products A_t^m to create the final agricultural good $\mathbb{A}_t^d$ using a CES function:

$$\mathbb{A}_t^d = \left[\left(\alpha_A\left(A_t^{i,d}\right)^{-\rho_A} + (1-\alpha_A)\left(A_t^m\right)^{-\rho_A}\right)\right]^{-\frac{1}{\rho_A}}.$$

The cost minimization (and perfect competition) implies:

$$\left(A_t^{i,d}\right)^{1+\rho_A} = \frac{\alpha_A}{\pi_t^{ad}}\pi_t^{a,f}\left(\mathbb{A}_t^d\right)^{1+\rho_A},$$

$$\left(A_t^m\right)^{1+\rho_A} = (1-\alpha_A)\frac{\pi_t^{a,f}}{\pi_t^{a*}}\left(\mathbb{A}_t^d\right)^{1+\rho_A},$$

$$\pi_t^{af} = \begin{cases} \left[\alpha_A^{\frac{1}{1+\varrho_A}} + (1-\alpha_A)^{\frac{1}{1+\rho_A}}\left(\pi_t^{a*}\right)^{\frac{\rho_A}{1+\rho_A}}\right]^{\frac{1+\rho_A}{\rho_A}} & \text{if } \rho_A \neq 0 \\ \left(\pi_t^{ad}\right)^{\alpha_A}\left(\pi_t^{a*}\right)^{1-\alpha_A} & \text{if } \rho_A = 0 \end{cases}.$$

2.3 Public Sector

The government spends for public good $\mathbb{G}_t$ and possibly can subsidy biofuel feedstock producers at rate τ_t^{sub}. In this model, the government collects the following taxes: labor taxes, VAT taxes, and excise taxes.

The government debt Δ_t (surplus if negative) evolves according to:

$$\eta_t\left[\Delta_{t+1} - \Delta_t(1+r_t)\right] = \mathbb{G}_t + \pi_t^b B_t \tau_t^{sub} - \tau_t^{ex} F_{yt} - \tau_{at}^{ex} F_{zt} - (F_{ht}+F_{at})\left(\tau_t^{ex} + (\tau_t^{ex} + \pi_t^f)\tau_t^{vat}\right) - \tag{26}$$
$$- \pi_t^{cf}\tau_t^{vat}\mathbb{C}_t - \tau_t^{vatA}\pi_t^{af}\mathbb{A}_t^d - \tau_t^l\left(w_{at}L_{at} + w_{ht}L_{ht}\right) - \left(\Pi_{at} + \Pi_{yt}\right)\tau_t^p.$$

In dynamic simulations, we assume that the government adjusts $\mathbb{G}_t$ so as to keep the $\mathbb{G}_t/\mathbb{Y}_t$ ratio constant. The debt is denominated in the international currency.

2.4 Identities

The model is closed by the following set of identities. The fuel market clears:

$$\mathbb{F}_t^d = F_{ht} + F_{at} + F_{yt} + F_{zt} + F_{xt},$$

where F_{xt} are net exports of fuel and the price is determined internationally π_t^f.

The food market clearing is

$$\mathbb{A}_t^d = A_{ht} + A_{at}.$$

The balance of payments is given as:

$$W_{t+1} - (1 + r_t) W_t + \Delta_{t+1} - \Delta_t (1 + r_t) = \mathbb{X}_t - \mathbb{M}_t + \pi_t^{a*}(A_t^x - A_t^m) - \pi_t^o O_t + \pi_t^f F_{xt}.$$

The other two identities are given in Equations (17) and (18) above.

2.5 Solution techniques

Because of the consumption Euler equation (7) and the capital accumulation equations (3) and (11), the model is dynamic and therefore, one has to make an assumption how expectations of future utilities and future investment returns are made. One possibility is to make a perfect foresight assumption, i.e., that the subjects form expectations rationally. We do not follow this option for three reasons: (i) it is technically challenging, (ii) it would require to make explicit assumptions about the policy instruments (tax rates and subsidies) and world prices (especially oil and food prices) into the indefinite future, and finally (iii) it is probably unrealistic.

Therefore, we opt for the alternative of adaptive expectations. We basically assume that agents form the expectations of future variables (i.e., the future returns on capital) adaptively, using the exponential smoothing [14] . The exponential smoothing is a popular practice in business and therefore, our assumption may not be completely unrealistic. If the formation of the expectations is thus anchored, the dynamic simulation can be represented as a sequence of static problems, which are easier to solve.

In this respect, it is also interesting to mention that the recent paper, Féménia and Gohin (2011), finds that the choice of the expectation formation does not

[14] See, e.g., Hyndman et al (2008) for a modern exposition of exponential smoothing.

influence much the results of applied general equilibrium models with the agriculture sector.

3 Simulations

3.1 The benchmark projections

In this section, we use the model to simulate a selected policy scenario for the time period 2011 – 2025. But before these simulations, we will describe the benchmark projection. This benchmark projection is intended to predict a situation without any introduction of new policy measures, but with the permanent changes in real prices in the converging economy. This projection is calibrated to reflect the equilibrium trajectories of the GDP growth and real exchange rate appreciation taken from Brůha et al (2010) and Brůha and Podpiera (2011).

The main characteristics of the benchmark projection include:

- an average growth rate of the labor augmenting technological progress in the intermediate sector ζ_{ly} by 5% p.a.;
- an average growth rate in the export demand function ζ_x by 2% p.a.;
- an average growth rate of the technological progress in the agricultural sector ζ_{la} by 1% p.a.;
- an average growth rates of real world prices of motor fuels and oil by 2 % p.a.

The first two assumptions are able to generate the GDP growth and equilibrium real exchange rate similar to projections in Brůha and Podpiera (2011). The third assumption is responsible for relative underdevelopment of the agricultural sector and increasing the inequality between agricultural and non-agricultural households. The final assumption reflects the long-run expected growth in oil prices, i.e., the Hotelling rule.

The results for this scenario are shown at Figure 2 in blue solid line. The figure shows the evolution of selected variables as a percentage index from the initial situation in 2010. This figure reveals the likely unequal development in the two sectors. The wages and real expenditures of non-agricultural households are expected to nearly double during the period of next 15 years, but this is not so true for the agricultural households. This unequal development would translate as an increase in inequality between the two group of households.

Still, the production of and wages in the agricultural sector rise by more than the corresponding productivity. This is caused by the trickle-down growth from the other sector. The trickle-down growth has two reasons. The first reason is the increase demand for food by the other agent and as the food has an important domestic component, it rises the demand for domestic agricultural production. This effect would not be present, if the substitution between domestic and foreign agricultural products were high. Second, the high domestic productivity of the intermediate sector, along with the real exchange rate appreciation, makes investments relatively cheap, which benefits also the agricultural sector.

Interestingly, the increase in world commodity prices (oil, fuel) does not benefit the domestic agricultural sector. On the one hand, it boosts the demand for biofuel feedstock (and thus for the whole agricultural production) and thus it increases its relative productivity relative to other sectors, but, on the other hand, it also increases production costs in the economy. For the calibration to the Czech economy, both effects roughly cancel each other.

3.2 A policy scenario: achieving the 10% target

In this scenario, we consider an introduction of the 10% target by the year 2020 as required by the Directive 2009/28/EC. We assume that this target will be achieved using slowly increasing production subsidies, and we investigate two ways of financing this subsidy: (a) the subsidy will be financed by an increase in the labor taxation, (b) the subsidy will be financed by an increase in excise tax on fuels. In both scenarios taxes rise so as to keep the government debt and public spending the same as in the benchmark scenario. The assumptions on technologies remain the same as in the benchmark projection.

Figure 2 overviews the simulation results. The figure compares three simulations: the benchmark, and the two alternative ways of financing the target. First, the way of financing the subsidy via increasing labor tax is clearly inefficient (see the green dash-dot line). Both sectors and both households are hurt. The before tax wage in the agriculture sector increases, but the increase is not enough to balance the increase in the tax rate, its real expenditures fall relative to the benchmark. The effect on the non-agricultural household is not so significant: although his after-tax wage falls also below the benchmark, his other income sources are almost intact (as the impact on the intermediate sector is rather small), and therefore his real expenditures do not fall as much as for the agricultural households. To summary, such a scenario would be not only inefficient on average, but it would also increase the inequality between the two types of households.

The second scenario (see red dot line in the figure) seems to be less inefficient.

It affects the production and wages in the intermediate sector, but less than in the previous case. The reason is that such a scenario induces substitution from imported energy sources (oil) towards domestic energy sources (i.e., the biofuel feedstock), which improves the trade balance and leads to a more favorable terms-of-trade. The economy can thus buy imported inputs more cheaply and that relatively boosts the production [15] . This effect is responsible for the fact that after-tax wages and real expenditures of the non-agricultural households do not fall as much as if the subsidy were financed by the labor tax. Note, however, that this effect would not be present, if the exports were highly price elastic. If exports were very elastic, the trade balance would be adjusted by quantities rather than prices and the terms-of-trade effect will be negligible.

The effect on the agricultural sector and household is interesting. In the long-run, the scenario boosts her welfare (relative to the benchmark case), as both real after-tax wages and real expenditures increases relative to the benchmark and so does the raw agriculture output. This is caused by the demand increase originated in the fuel producing sector and this can be considered as a favorable supply shock for the agriculture sector. However, short-run effects are not so favorable: the reason is that – in the short run – the capacity in the agriculture sector are quasi-fixed and therefore the increase in the demand leads to higher relative agriculture prices. Consumers (in both sectors, as well as foreign consumers) react more quickly here than the supply, which explains the short-run effect. However, in the long-run, the favorable supply shock overweighs the short-run reaction and the inequality between the two sector falls.

Note that this scenario is – in the framework of this model – equivalent to the mandatory blending quota. The reason is following: the scenario would cause the same relative price changes as the mandatory blending quotas if the income from the increased excise tax is exactly equivalent to the amount of subsidy needed to achieve the target. This is due to constant returns-to-scale in the fuel producing sector.

4 Conclusions

In this paper, we introduced a CGE models with heterogenous households, with a detailed agriculture sector, and with features important for transition countries in Central Europe. The model is calibrated for the Czech Republic.

[15] In fact, one can think of such policy as of ‘invisible’ tariffs, i.e., as of a clever way of shifting a part of the tax burden on foreigners. In a different context, the role of indirect taxes as ‘invisible’ tariffs is discussed and assessed *inter alia* by Naito (2000) or William (1999).

We use the model to simulate and compare alternative approaches to achieving the 10% target as required by the Directive 2009/28/EC. We considered a gradual introduction of subsidies for biofuel feedstock products so that the target is achieved by 2020. If the subsidy is financed by the increase in labor taxes, the policy would not only cause economic distortion, but it may hurt the agricultural sector even relatively more.

If the subsidy is financed by the increase in excise tax on motor fuels (or by mandatory blending quotas, which is equivalent instrument in our model), then the distortions are alleviated and the agricultural sector may benefit from this policy measure. This shows that it is not irrelevant how the target is achieved.The reason why this scenario is more beneficent for the economy is the favorable terms-of-trade effect, which is caused by the shift from imported sources (oil) to the domestic source (biofuel feedstock). This effect would not be present if the domestic exports were very price elastic, as in this case, the terms-of-trade effect would be unimportant. However, the finding that the agriculture sector would benefit relatively more does not depend on this terms-of-trade effect.

Acknowledgment

This research was supported by a grant from the CERGE-EI Foundation under a program of the Global Development Network RRC X-101 ‘Implications of biofuel promotion for a transition country’. All opinions expressed are those of the author(s) and have not been endorsed by CERGE-EI or the GDN.

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Fig. 1. The Agriculture Sector

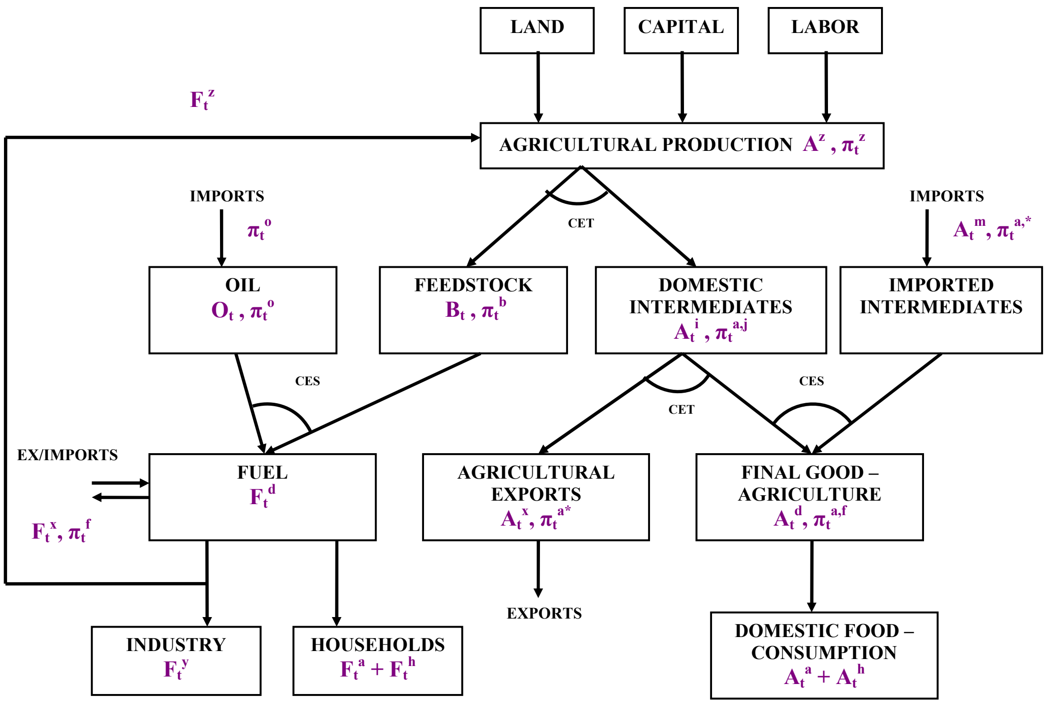

Fig. 2. Simulation results