Economic Effects of Biofuel Promotion. An Assessment with a World Dynamic CGE Model

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Introduction and Structure of the Presentation

Structure of Presentation

- Motivation
- Description of the Core of the Model
- The Bellman's Equation for Oil Producing Region and Solution
- Data, Parametrization and Calibration
- Preliminary Results - Simulation

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Why Biofuels?

Biofuels as Policy Issue

the EU

- Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport
- Directive 2009/28/EC on the promotion of the use of energy from renewable sources
- the aim is to substitute 10 % of traditional fossil fuels (gas oil, gasoline) by biofuels (Fatty Acid Methyl Esters - Biodiesel, Bioethanol, etc.) by the year 2020

the U.S.

- American Energy Independence and Secuirity Act
- The aim is to place 15 bn. gallons of biofuels on the market by the year 2015 and 36 bn. gallons by the year 2022

Czech Republic

- Air Protection Act 86/2002 Coll.
- The aim is to place annually 6 % of biodiesel and 4,1 % of bioethanol on the market

Why Biofuels?

Economic Questions Appeared in Connection with Biofuels

Economically related issues

- Effects on employment (positive or negative and in which sectors)
- Effects on prices of motor fuels (decrease due to competition or increase due to more expensive biofuels)
- Effects on consumers (end use prices)
- Effects on regions (decreasing dependency on crude oil coming from politically volatile regions?)

Why CGE Model?

The specifics of Biofuel Production/Consumption Chain

Specifics of Biofuel Chain

- Production chain begins in agriculture (first generation biofuels, also second generation biofuels)
- Land Competition in Agricultural Production
  - Among different biofuels - (eg. crop for biodiesel or bioethanol production ?)
  - Between different biofuels and food (eg. sugar cane for sugar or bioethanol ?)
- Land Competition with other Agricultural Uses and Other Types of Land Area
  - Pastures
  - Forests
- Manufactured in industry sector (competition between refineries and biofuel producers)
- Biofuels as well as their feedstock are largely traded (agricultural products like rapeseed or corn, maize, sugar cane, etc.)

Description of the core of the model

Regions

Regions in the Model

- the Czech Republic,
- the rest of the EU-27,
- the OPEC countries,
- the rest of the OECD,
- rest of the former USSR,
- the rest of Asia,
- the rest of Africa,
- the rest of Latin America,
- the rest of Europe.

Regional Characteristics

- Endowed with an arable land $\mathcal{L}$
- Populated by a representative agent
- Agent consumes final good C_{it}, food A_{it}, public good G_{it}, and supplies an inelastic amount of labor L_{it}

Description of the core of the model

Social Planner Problem - objective function

Objective Function

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

Description

- $\mathcal{E}_0$ is the expectation operator
- β is the parameter of the intertemporal rate of substitution
- subindex i refers to regions
- the subindex t refers to time

Description of the core of the model

Social Planner Problem - sectoral production functions

Production function in the final-good sector

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

Description

- $\mathbb{Y}$ is the neoclassical production function, we assume the Cobb-Douglas form of this function
- L^{y}_{it} is the labor used in that sector
- F_{it} is the fuel used in that sector
- ζ_{it} is the labor augmented technological progress

Description of the core of the model

Social Planner Problem - sectoral production functions

Production function in the fuel producing sector

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

Description

- $\mathbb{F}$ is the production function of CES form
- O_{it} are conventional fossil fuels used for the production of fuel
- B_{it} are agricultural inputs
- ζ_{it}^{b} is the technology progress
- T_{it} is a back-stop technology
- ζ_{it}^{t} is the corresponding technological progress
- F_{it}^{d} is the domestic production of fuels

Description of the core of the model

Social Planner Problem - sectoral production functions

Agricultural production function

$$A_{it}^{d} + B_{it}^{d} = \mathbb{A}(L_{it}^{a}, \mathcal{L}_{i}, \zeta_{it}^{a})$$

Description

- $\mathcal{L}_i$ is the agricultural land in region i
- L_{it}^{a} is labor employed in agriculture
- ζ_{it}^{a} is the exogenous technological progress

Description of the core of the model

Social Planner Problem - sectoral production functions

Oil extraction production function

$$O_{it}^{d} = \chi(K_t^o, L_t^o, O_{it}^{e})$$

Description

- χ is the production function in oil extracting sector capturing that it is costly to extract the oil using capital and labor, for oil non-extracting country holds: $O_{it}^{d} \equiv 0$ (and also $O_{it} \equiv 0$)
- K_t^o is sector specific capital in oil extracting sector - this type of capital can not be used in final good sector
- L_t^o is labor employed in oil extracting sector
- O_{it}^{e} is oil extraction in region

Description of the core of the model

Social Planner Problem - Identities

GDP

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

Description

- 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^o_{it} are investments used in the oil extracting sector
- K^o_{it} is capital used in the oil extracting sector with
- ϕ^o is the corresponding adjustment cost function (for oil non-producing regions $I^o_{it} = K^o_{it} = 0$)
- X_{it} are net exports of the final good
- $\varkappa(T_{it})$ is the cost of using the backstop technology
- Y_{it} is the production of the final good

Description of the core of the model

Social Planner Problem - Identities

Regional Fuel Equilibrium

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

Description

- F_{it}^{x} are net exports of fuels from region i
- F_{it} is domestic consumption of fuels
- F_{it}^{d} is domestic production of fuels

Regional Agricultural Equilibrium

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

Description

- A_{it}^{x} are net exports of food from region i
- A_{it} is domestic consumption of food
- A_{it}^{d} is domestic production of agricultural products

Regional Biofuel Equilibrium

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

Description

- B_{it}^{x} are net exports of biofuels from region i
- B_{it} is domestic consumption of biofuels
- B_{it}^{d} is domestic production of biofuels

Description of the core of the model

Social Planner Problem - Identities

Regional Oil and Oil Reserves Equilibrium

$$O_{it} = O_{it}^{d} - O_{it}^{x}$$

$$R_{it+1} = R_{it} - O_{it}^{e} + \zeta_{it}^{r},$$

Description

- O_{it}^{x} are net exports of oils from region i
- O_{it} is domestic consumption of oil
- O_{it}^{d} is domestic production of oils
- R_{it} are oil reserves
- ζ_{it}^{r} are shocks to oil reserves (such as new discoveries)
- for **oil non-producers** holds:
  $R_{it} \equiv 0$, $O_{it}^{d} \equiv 0$, $\zeta_{it}^{r} \equiv 0$, and thus $-O_{it} = O_{it}^{x} \leq 0$

Description of the core of the model

Social Planner Problem - Identities

Balance of Payments

$$X_{it} + \pi_{bt} B_{it}^{x} + \pi_{at} A_{it}^{x} + \pi_{ft} F_{it}^{x} + \pi_{ot} O_{it}^{x} + (1 + r_t) W_{it} = W_{it+1}$$

Description

- W_{it} is the net worth of region i
- π_{bt}, π_{at} , π_{ot} are relative prices of agricultural products and oil
- The agricultural production function postulates $\pi_{bt} \equiv \pi_{at}$

Description of the core of the model

Social Planner Problem - Identities and Capital Accumulation

Labor Market Clearing Condition

$$L_{it} = L_{it}^{y} + L_{it}^{a} + L_{it}^{f} + L_{it}^{o}$$

Description

- for **oil non-producers** holds:
  $L_{it} = L_{it}^{y} + L_{it}^{a} + L_{it}^{f}$

Capital Accumulation

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

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

The Description of the Model

Social Planner Problem - Bellman's Equation for Oil Producers

Bellman's Equation for Oil Producing Region

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

The Description of the Model

Social Planner Problem - Solution

Solution

- $u_{ct} = u_{gt} = u_{at}/\pi_{at}$
- $\mathbb{Y}_{F_t} = \pi_{ft}$
- $\mathbb{Y}_{Lt} = \pi_{at}\mathbb{A}_{Lt} = \pi_{ft}\mathbb{F}_{Lt}$
- $\pi_{ft}\mathbb{F}_{Bt} = \pi_{at}$
- $\pi_{ft}\mathbb{F}_{Ot} = \pi_{ot}$
- the Euler equation: $u_{ct} = \beta\mathcal{E}_t(1 + r_{t+1})u_{ct+1}$
- the inter-temporal allocation of capital:
  $u_{ct}(1 + \phi_{It}) = \beta\mathcal{E}_t u_{ct+1}\left[\mathbb{Y}_{Kt+1} + \phi_{Kt} - (1 - \delta)(1 + \phi_{It+1})\right]$
- Hotelling Rule: $\pi_{ot}u_{ct}\chi_{Ot} = \beta\mathcal{E}_t u_{ct+1}\pi_{ot+1}\chi_{Ot+1}$

The Description of the Model

Closure of the Model

Determination of Prices

- The equations below 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 $\sum_{i \in \mathcal{I}} [W_{it+1} - (1 + r_t) W_{it}] = 0$.

Closure of the Model

- $\sum_{i \in \mathcal{I}} X_{it} = 0$
- $\sum_{i \in \mathcal{I}} \overline{A}^x_{it} = 0$
- $\sum_{i \in \mathcal{I}} F^x_{it} = 0$
- $\sum_{i \in \mathcal{I}} O^x_{it} = 0$

The Description of the Model

Parametrization and Solution Technique

Production and Utility Functions

- $u\left(C_{it}, G_{it}, A_{it} | \xi_{it}\right) \equiv \log C_{it} + \xi_{it}^{g} \log(G_{it} - \overline{G}_{i}) + \xi_{it}^{a} \log(A_{it} - \overline{A}_{i})$
- $\mathbb{Y}(K_{it}, \zeta_{it} L_{it}^{y}, F_{it}) = K_{it}^{\alpha_K} \left(\zeta_{it} L_{it}^{y}\right)^{\alpha_L} F_{it}^{1-\alpha_K-\alpha_L}$
- $\mathbb{F}(O_{it}, \zeta_{it}^{b} B_{it}, L_{it}^{f}) =$
  $\left(\alpha_o O_{it}^{\rho_o} + (1-\alpha_o)\left(\zeta_{it}^{b} B_{it}\right)^{\rho_o} + \left(\zeta_{it}^{t} T_{it}\right)^{\rho_o}\right)^{\frac{\alpha_f}{\rho_o}} \left(L_{it}^{f}\right)^{1-\alpha_f}$
- $\mathbb{A}(L_{it}^{a}, \mathcal{L}_{i}, \zeta_{it}^{a}) = \mathcal{L}_{i} \zeta_{it}^{a} \left(L_{it}^{a}\right)^{\alpha_a}$

Boundedly Rational Agents - Adaptive Expectations

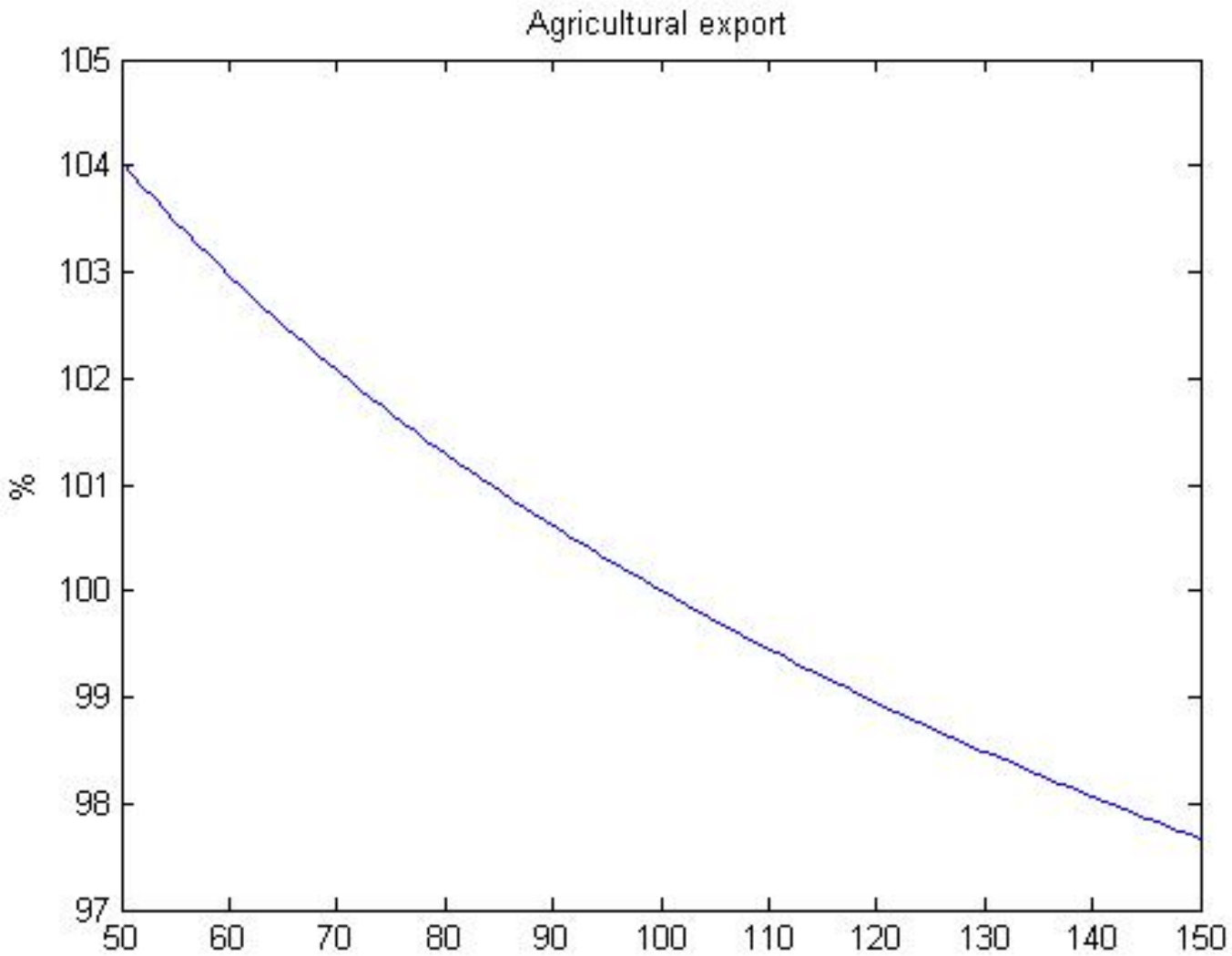
The Description of the Model

Calibration

- The utility function (average shares of food in consumption)
- Government utility function (national accounts GNT spending)
- Production functions (cost structure in industries)
- International trade in oil and agricultural products replicate the trade balances
- β takes conventional value from literature (0.95)
- Sample averages of last 5 years
- Improving calibration - exogenous processes on history
- Solution: first-order dynamic system with some unobserved variables

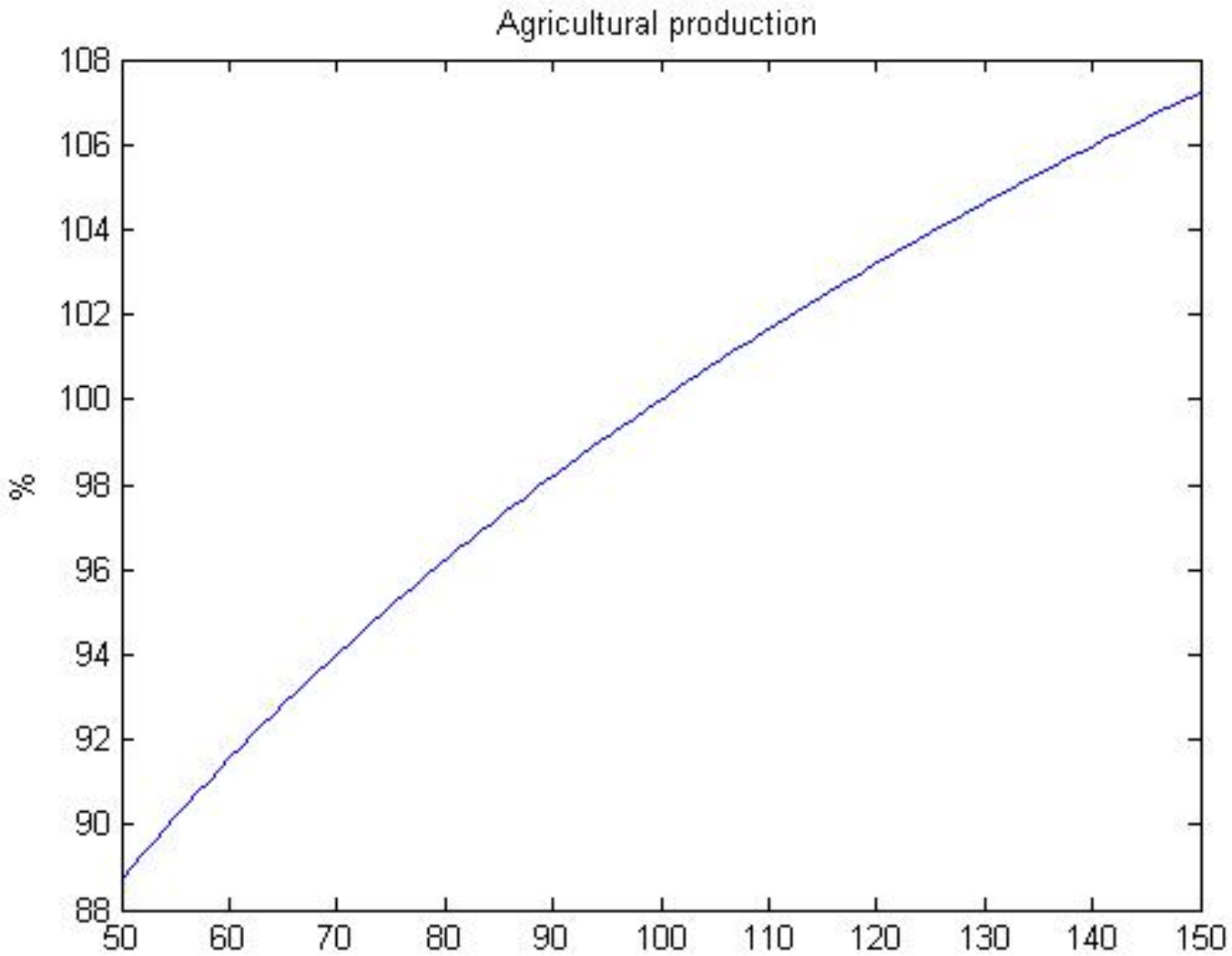
An Illustrative Simulation

Agricultural Export



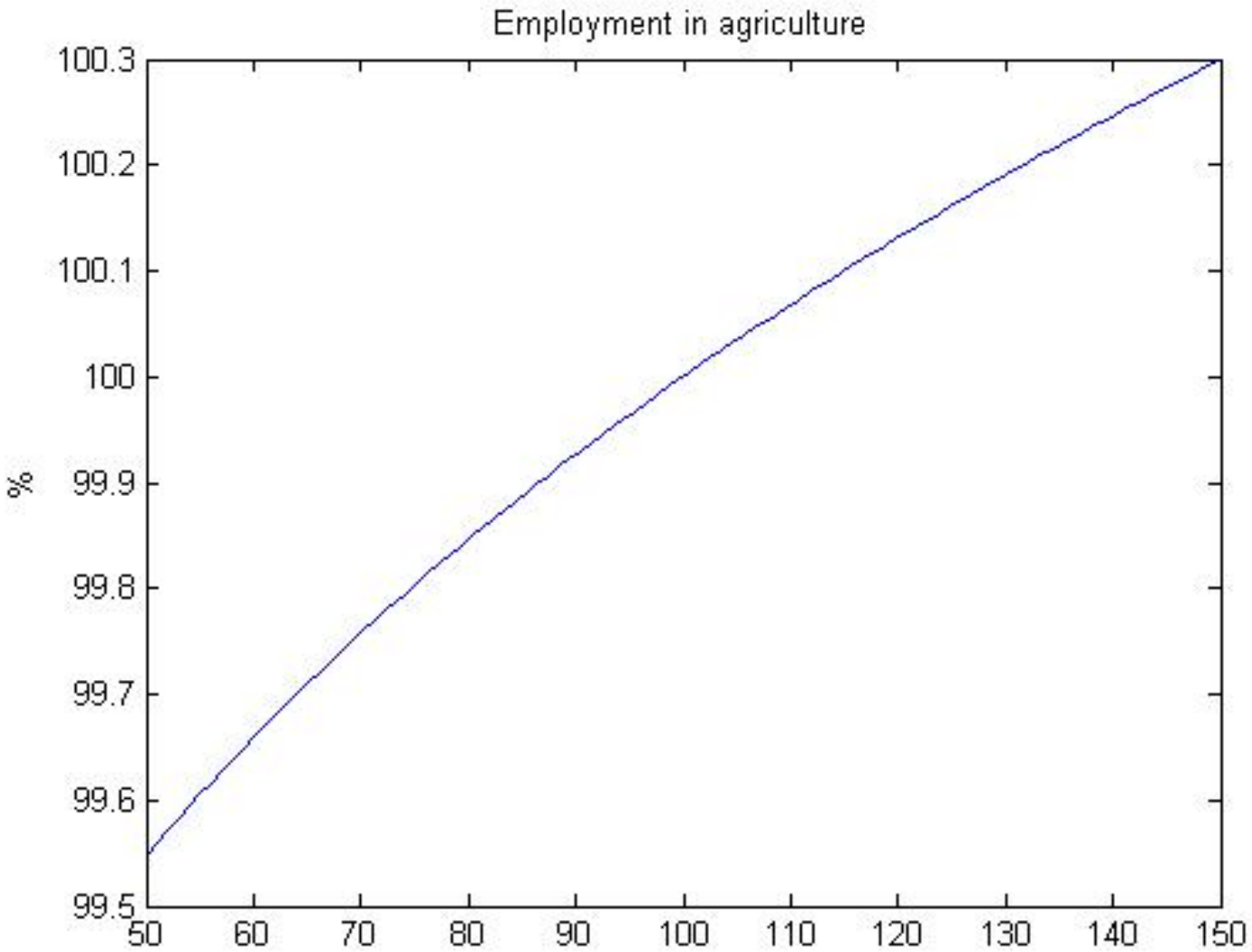
An Illustrative Simulation

Agricultural Production



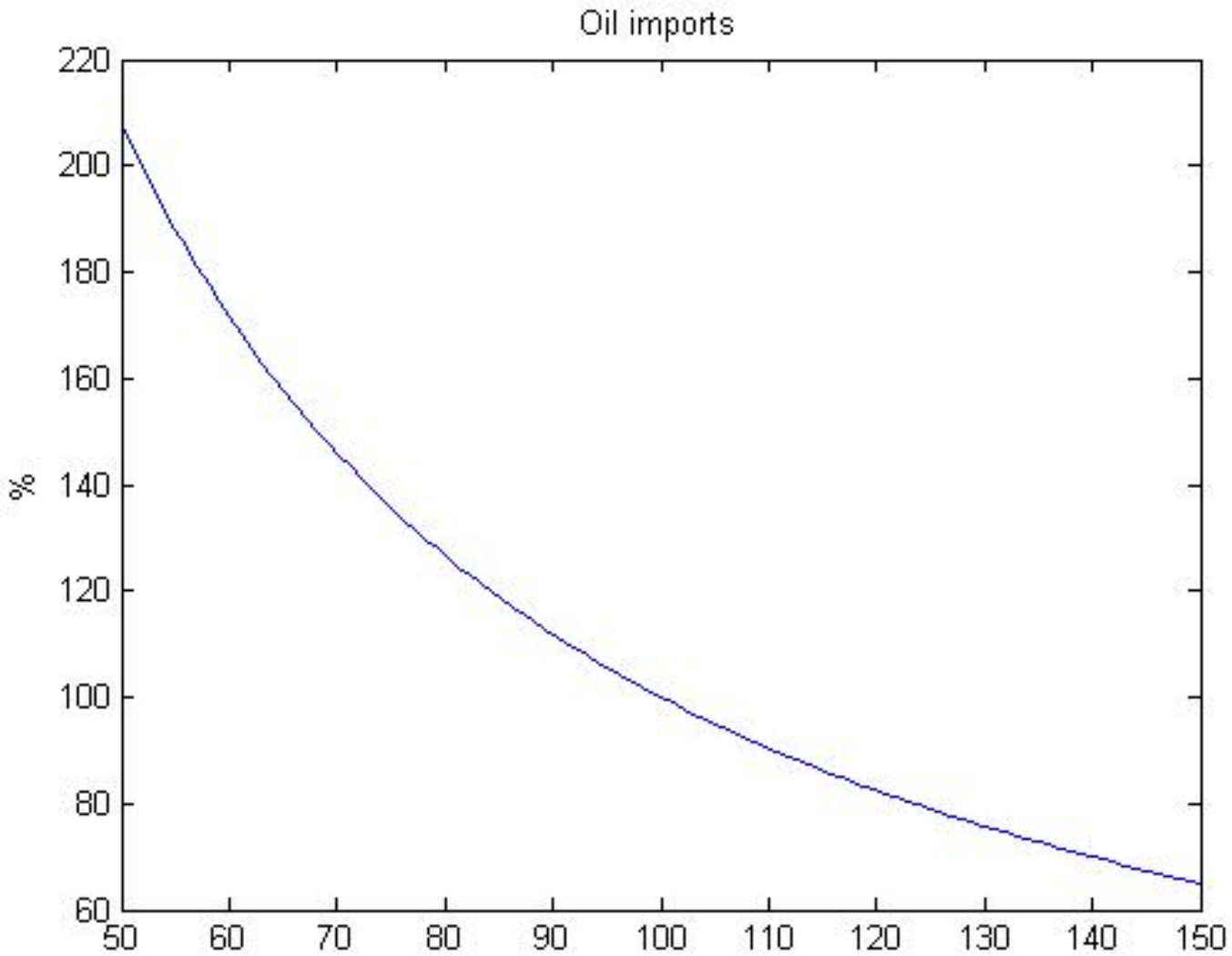
An Illustrative Simulation

Agricultural Employment



An Illustrative Simulation

Oil Imports



Conclusion

Future Extensions

- Competitive Economy for the Czech Republic
- Parameter Checks and Possible Estimation

Possible Applications

- Assessments of Policy Impacts in Selected Regions
- Dynamics of Selected Commodity Prices