WORKING PAPERS

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INTERACTIONS BETWEEN TRADE AND ENVIRONMENTAL POLICIES IN THE CZECH ECONOMY

Interactions between trade and environmental policies
in the Czech economy

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Abstract

Pollution charges are directly applied on exported and domestic, but not imported commodities. We investigate how environmental taxation affects foreign trade in the Czech Republic. Using computable general equilibrium modeling with bottom-up approach, we consider a small-open economy with endogenous unemployment, fixed exchange rate, ten types of taxes and six air-pollutants. Emission reduction is possible through substitution with less polluting inputs, a reduction of output, or abatement. The results show that the imports should not be affected, except coal and electricity. Exports will increase in the light and the biomass industries. The overall effect on the trade balance is slightly negative.

Keywords:
calibration, competitiveness, computable general equilibrium modeling, pollutions, taxes

JEL:
C68, H23, Q56

I. INTRODUCTION

The European Commission encourages the use of market-based instruments for environmental policies in member states. Environmental taxes, according to Eurostat, refer to energy taxes, transport taxes and ecotaxes. Energy taxes have been implemented in the Czech Republic in 2008, in accordance with the European Commission's tax policy. The Czech government plans to implement a carbon tax and to increase other environmental tax rates before 2016. There is a widespread opinion that these taxes may increase the costs of affected industries and reduce their economic performance, including their international competitiveness (Boehringer, Conrad, and Loschel 2003, Kiuila and Sleszynski 2003, Proost and van Regemorter 2004, Wissema and Dellink 2007). We show that this is not the case for the Czech economy, where some affected sectors (like minerals and road transportation) will not lose international competitiveness.

Using the computable general equilibrium (CGE) approach, we will compare two distinct states of the economy, before and after the implementation of the reform. These models are able to quantify the direct and the indirect effects of emission charges on many aspects of the economy, like its structure, predicted change in the allocation of resources. CGE modeling, as any other economic modeling, is a simplification of reality. Orrell and McSharry (2009) state that it cannot be a good forecasting tool for several reasons: equilibrium in economies is assumed, everything is too simplified, results are underestimated, and numerical models (including all economic models) usually are too sensitive. We agree that numerical models have limitations and a multidisciplinary approach should be considered, but we propose to take few aspects into account. First, the main task of computable general equilibrium models is to find out relationships between markets. The equilibrium approach does not imply a suggestion that the real world passes from one equilibrium to another, but it allows us to recognise the demand-supply mechanisms.

Second, we are neither able not willing to replicate all details of reality with any model, but we can take into account the key characteristics of the economy. A simple good model is more useful than a complicated, but an incorrect one. The model that we propose is carefully designed in order to replicate important details of the Czech tax system and to simulate interactions between environmental and trade policy. We distinguish 10 types of taxes, but we ignore export quotas and import tariffs because they are relatively unimportant in the Czech economy. On the other hand, CGE models are "black boxes" for most readers. We open the box and explain the details of the model. The paper describes the assumptions about production and consumption process, factors and goods markets, domestic and foreign trade, public and private demand.

Third, policy makers need to make their decisions and economists' job is to provide forecasts. Assumptions in economic models are matter, but the trick is to adjust the assumptions so that every new economic model fits the reality better than the previous. Economic modelling can be improved if modelers play with different assumptions.

When we calibrate a CGE model, it does not automatically mean that the model will generate non-biased results. If some variables were not activated in the benchmark equilibrium, but it is just activated in a scenario, there is no guarantee that this variable was implemented properly until we make additional tests (calibration process alone will not suffice). This is an immediate source of "strange" results. The model that we propose has been tested with different assumptions like normal versus inferior goods, economy-wide versus sector-specific abatement, different levels of elasticity parameters, tax rates, etc.

The model for the Czech economy is the Arrow-Debreu model of a small-open economy. It has an aggregate representation of 20 sectors, 7 factors, 1 household and a government corresponding to the standard structure of the Czech 2005 input-output table. Emissions of the following air pollutants through fuel combustion and technological process is determined by the model: SO_2, NOx, CO_2, CO, PM, VOC. Emission reduction is possible through a substitution with less polluting production factors, a reduction in activity level and an increase in abatement activity. The abatement sector contains bottom-up technologies with decreasing returns to scale. Thus a combination of bottom-up and top-down modelling is applied. In addition, market imperfections are imposed on the labor market.

The outline of the paper is the following. In section 2, we provide a policy background and discuss economic modelling of the Czech environmental policy. In section 3, we analyze the static setting of the model and describe the required data. A calibrated share form of the functions is applied, rather than a traditional coefficient form. In section 4, the simulation results are analysed. Section 5 concludes.

II.   POLICY AND MODELLING BACKGROUND

The use of economic instruments in environmental regulation in the Czech Republic has a long history (EC 2001). Pollution charges have been gradually introduced since the 60s: air emission charges in 1967 and wastewater charges and 1979. However, in the centrally planned economy, environmental regulation did not play a significant role. The current tax system in the Czech environmental policy was introduced in the early 90s. It consists of emission charges for some air pollutants, air emission non-compliance fee, water charges, solid charges, charges for dispossession of agricultural and forest lands, and mining charges.

The Czech authorities started to prepare an ecological tax[1] reform in 2000. The initial idea was based on higher energy taxation, then it evolved towards carbon taxation, and more recently it has been focusing on higher taxation on air-pollutants. According to European Environment Agency, the system of environmental charges in the Czech Republic is comprehensive and complex with relatively low rates (EEA 2008). Several products are subject to a reduced VAT targeting energy conservation and/or

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[1]The terms 'tax', 'fee', and 'charge' are used as synonyms in this paper.

environmental protection. The low level of environmental charges in the years 1991-2004 has had no observable effect on either the energy demand or on the state of the environment.

The current tax structure and its departure from the revenue optimal state will determine how the new environmental taxes will affect the economy, including employment and competitiveness. Pollution charges are applied directly on exported and domestic goods, but not on imported goods. The magnitude of the effects on competitiveness of the higher environmental taxation depends, among other things, on the contribution of trade in pollution intensive products (i) to GDP and (ii) with countries where environmental taxes are not in place. The main commercial partners of the Czech Republic are geographical neighbors. The possibility of relocation of Czech firms to the neighbouring countries due to higher taxes is rather improbable, since those countries already have relatively high environmental tax rates. Altemeyer-Bartscher, Rubbelke, and Sheshinski (2010) shows a mechanism to induce one country to raise environmental tax rates by another country and to attain Pareto-efficient outcome. The extent to which environmental taxes in the Czech Republic would affect its competitiveness and trade level with its main partners would depend on the magnitude of the new rates, relative to the tax level observed in other countries.

A change in fiscal policy might harm the economy and reduce overall welfare; or, on the contrary, technological progress might be enhanced and employment boosted. To evaluate the overall effect, economic models have been developed and gradually utilized. One of the very first CGE models of the Czech economy has been built by Martin and Skinner (1998). It is a static model of an open economy based on 1992 data. The production process is described by a CES function, the consumption - by a Cobb-Douglas, and no environmental feedbacks are considered. The Authors made a simulation of revenue-neutral shifts in the tax on electricity with an associated reduction of the tax on labor. The results demonstrated that the taxation shift improves welfare.

Bruha (2002) uses a CGE model of a small open economy in the evaluation of effects of increase in fossil-fuel prices in Czech Republic with a simultaneous decrease in labor taxes. Two possibilities of the state of labour market were considered: inelastic labour supply and labour-leisure choice. In both cases, the presence of the so-called double dividend has not been proven. A different versions of the model have been frequently used by Czech researches to evaluate optimal taxation (Bruha and Scasny 2005). The dynamic version (the "HANI" model) was used for creating recommendations of the first phase of the environmental tax reform. A disadvantage of the HANI model is its structure of the production process - there are no energy production factors. Our model is expected to be used for the simulation of the second phase of the reform.

Another environment-related issue are the prices of oil products. Janovskij and Rojicek (2004) presented a CGE model that is characterized by a relatively rigid production side of the economy. The inputs and the capital are assumed to be used in fixed proportions. There are sectoral exogenous wages and unemployment is allowed. The

simulation of increased oil prices showed a negative impact on the Czech trade balance, as expected. The improved version of the model is used by the Czech authorities to simulate energy policy (Dybczak et al., (2008)).

There are a few other CGE models for the Czech economy (for example the model prepared by the Czech National Bank), but they are not adequate for environmental policy simulations. Beside national models, there are also global models, like the GEM-E3 (E3M-Lab 2008), prepared by international teams but they are proprietary.

To summarize - modeling the impacts of environmental policy in the Czech Republic has been developed only in the last decade. The main reasons for the delay were (i) the lack of quality data which could be blamed on the transition from the planned economy to market based and (ii) a gradual implementation of statistical standards. Our contribution to the modeling issues of environmental policy for the Czech economy covers several aspects. First, our CGE model takes directly into account many different sources of air-pollution emissions. Second, a more flexible demand system is incorporated, as compared to the existing Czech models. Third, we consider ten types of taxes in the benchmark equilibrium: output tax, value-added tax, two types of emission charges, corporate income tax, personal income tax, two types of payroll tax, excise tax, and other taxes on products. Next, unemployment is endogenously determined through a wage curve. Finally, abatement technologies are taken into account. We explain these aspects in detail in the next two sections.

III.   STATIC FRAMEWORK OF THE MODEL

DATA

CGE modeling requires a single-period inter-industry transaction table, as opposed to the time series, usually required in macro-econometric modelling. The database for the Czech model is a single-year set based on the national input-output table (IOT) supplemented with other data, like the data on the stocks of capital and labour or the pollution emission. The latest available input-output table describes the Czech economy at the end of the year 2005 and, which is our benchmark equilibrium.

Both the rows and the columns of the original Czech IOT represent products. We assume that each sector produces a sector specific output and no other sector may produce the same product. This means that the products classification in our model is the same as sectoral classification. We have aggregated the economy into four broad groups of products: energy, production, services, and transport. These four groups has been disaggregated into 19 products based on economic characteristics (market power, protection, and the tradability of products) and environmental impacts (emission volume). There is an additional sector that can reduce pollution emission through abatement process. The details of the classification are given in Table 1. It includes 5

Table 1: Aggregation in the model

#	final products (with abreviations)	#	production factors	#	pollutants
1	Manufacturing (`MANUF`)	1	Labour (L)	1	SO2
2	Minerals (`MINERAL`)	2	Capital (K)	2	NOx
3	Metallurgy (`METAL`)	3	Coal (C)	3	CO2
4	Energy intensive (`PAPER`)	4	Biomass (B)	4	CO
5	Energy non-intensive (`CLOTHES`)	5	Gas & crude oil (G)	5	PM
6	Chemicals (`CHEM`)	6	Coke & petroleum products (F)	6	VOC
7	Construction (`CONSTR`)	7	Electricity (E)		
8	Heating (`HEAT`)				
9	Food (`FOOD`)				
10	Agriculture (`AGRICUL`)				
11	Road transportation (`TRANSPR`)				
12	Other transportation (`TRANSP`)				
13	Market services (`SERV`)				
14	Public services (`SERVPUB`)				
15	Coal (`COAL`)				
16	Biomass (`FOREST`)				
17	Gas & crude oil (`GAS`)				
18	Coke & petroleum products (`PETRO`)				
19	Electricity (`ELEC`)				
20	Abatement (`ABATE`)				

energy products that represent the secondary production factors.

The model takes into account both the economy and the pollution aggregation. For the pollution aggregation, we have distinguished 6 air-pollutants, while all other pollutants are ignored. We also distinguish 3 main sources of emissions: energy combustion, non-energy combustion, and mobile sources. The data have been taken from the Air Pollution Emission Source Register (REZZO) provided by the authorized state institution, the Czech Hydrometeorological Institute (CHMU). Some emissions of particulate matter (PM) and volatile organic compound (VOC) in the database are not relevant to any sources defined in our model and we have ignored it.

We have incorporated emission coefficients instead of an emission function. Producers and households are both considered to be pollution emitters, i.e. we take into account emission coefficients per actor (19 producers[2] and 1 household), per pollutant (6 air-pollutants), and per source (combustion of coal, gas, oil, biomass, non-energy combustion, and mobile sources). It requires a mapping of the monetary flows from the

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[2]Abatement sector does not create any emissions.

IOT with corresponding physical flows from environmental balance. Thus, the relevant fuel consumption and the domestic production is combined with environmental data, in order to calculate both sector-specific and energy-specific emission coefficients for the selected air pollutants. As a result, we obtain 11 categories of emission coefficients.

PRODUCTION

A combined Leontief technology and a nested-CES production structure (Figure 1) is used to determine the output for each sector[3]:

- Intermediate demand $ID_{j,i}$ is composed of 14 non-energy inputs between which there is set zero elasticity of substitution. We may describe it by a Leontief structure[4]:

$$ID_{j,i} = id0_{j,i}\frac{N_i}{n0_i}$$

where $id0_{i,j}$ is the benchmark intermediate demand on input j by sector i, N_i is the output of sector i, $n0_i$ is the benchmark output.

- The demand for production factors - primary and secondary factors in Table 1 - is described by a nested separable-CES structure in order to allow for non-constant substitution between factors. For example, coal and biomass enter at the bottom nest with a constant substitution elasticity σ^{CB}, as illustrated by the following unit cost function:

$$\texttt{PCB}_i = \left(\theta_{c,i}\left(\frac{PA_c + te_{c,i} * \texttt{PNUM}}{pe0_{c,i}}\right)^{1-\sigma_i^{CB}} + (1 - \theta_{c,i})\left(\frac{PA_b + te_{b,i} * \texttt{PNUM}}{pe0_{b,i}}\right)^{1-\sigma_i^{CB}}\right)^{\alpha_i/(1-\sigma_i^{CB})}$$

where PCB_i is an implicit price of coal and biomass in the output price of sector i, PA_c and PA_b are the price of coal and biomass respectively, $pe0_{en,i}$ represent benchmark prices, $te_{c,i}$ and $te_{b,i}$ are emission charges resulting from consumption of coal and biomass, respectively, $\texttt{PNUM}$ is a price index, α_i is the returns to scale parameter[5], σ_i^{CB} is the elasticity of substitution between coal and biomass in sector i, $\theta_{c,i}$ is the value share of coal in the coal-biomass composite[6]. At the next level of the nested structure, gas and coal-biomass composite combine with

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[3]This section refers to 19 sectors out of 20. The abatement sector has a different characteristic and it will be discussed in a separate section.

[4]Following Boehringer et al. (2003), we use a calibrated share form of the functions, rather than traditional coefficient form. Both formes gives the same results, but the first form simplifies the calibration process.

[5]We assume constant returns to scale for 19 sectors, i.e. $\alpha_i = 1$.

[6]*Theta* is defined as the value of the factor added divided by the value of all factors taken into account until this stage of production process. This parameter substitutes two traditional parameters of CES function: scaling parameter and distribution parameter.
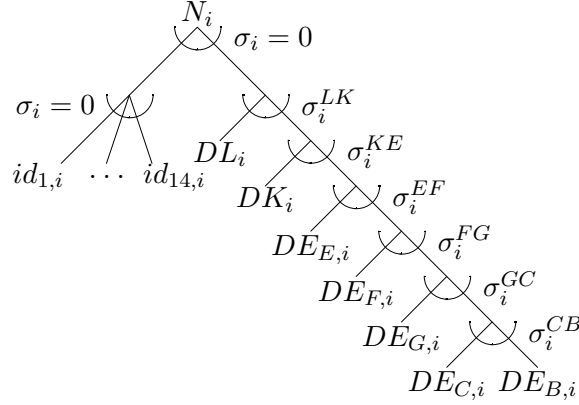
Figure 1: Production structure

another constant substitution elasticity σ^{GC}, etc. In the top nest, labour and composite capital-energy shows a trade off with a new value of σ^{LK}:

$$\texttt{PLK}_i = \left(\theta_{l,i} \left(\frac{PL(1+sp)}{pl0} \right)^{1-\sigma_i^{LK}} + (1-\theta_{l,i})(\texttt{PKE}_i)^{1-\sigma_i^{LK}} \right)^{\frac{1}{1-\sigma_i^{LK}}} \tag{1}$$

where $\texttt{PLK}_i$ is the implicit price of labour in the output price of sector i, $\texttt{PKE}_i$ is the implicit price of capital in the output price of sector i, PL is the uniform gross wage, sp is the payroll tax rate applied on employers, and $pl0$ is the benchmark labor cost. This is the final production factor composite.

In the last stage of creating the gross product, producers in each sector combine the purchases of the products of other sectors with the purchase of a composite factor, and no substitution is possible. Such specification of technologies allows for a comprehensive representation of the substitution possibilities in production through: (i) interfuel substitution within the energy aggregate and (ii) substitution between energy and other production factors. The model does not allow for intra-industry competition for inputs, because there is a uniform price for the output of each sector. The firms are risk neutral.

Both, primary and secondary, production factors are assumed to be homogenous and perfectly mobile between sectors. Primary factors are only mobile domestically.

Labour market

The neoclassical axiom of flexible wages is suspended in our model as the endogenous unemployment U is determined through a wage curve. The wage curve hypothesis (Blanchflower and Oswald 1995) states that wages are negatively correlated with local unemployment rates: high unemployment leads to lower wages. We distinguish four components of the labor price: personal income tax tl, payroll tax applied on employees sl, payroll tax applied on employers sp, and endogenous gross wage PL.

The is a fixed labour supply ls, while demand on labour is specified endogenously from

the CES function (1):

$$DL_i = dl0_i \left(\frac{\mathtt{PLK}_i * pl0}{PL(1 + sp)} \right)^{\sigma_i^{LK}} \frac{N_i}{n0_i}$$

where DL_i and $dl0_i$ is employment per sector i in the counterfactual and in the benchmark equilibrium respectively, $PL(1 + sp)$ is the labour cost.

Capital market

The capital market is simplified, as the static models assume no capital formation. This means that the capital supply (ks) is fixed (Figure 2). We define 'capital' as the sum of fixed capital (fk) and net operating surplus (π), because there is no profit under constant returns to scale. In reality firms generate profits and in order to take that into account we reformulate the profit condition: $\pi + TC = TR$, i.e. in order to generate revenue TR, we require $(\pi + TC)$. There are several methods of implementing the profit into the CGE model:

- If profit is a parameter in the model, then it creates distortions in the economy, similar to taxes.

- If profit is a variable in the model, then we have to incorporate it into the production function.

    - If we include π as a single production factor into the production function, then it is difficult to interpret this 'factor' because there is no optimal amount of surplus - the more surplus we have, the better we are.

    - If we aggregate π with fk, we treat it as a capital factor. Another reason for applying this aggregation, is that since the quality of capital data is usually poor, it is better to have aggregated rather than disaggregated values (i.e. gross operating surplus).

The cost of capital consists of the net price of capital (PK) and the corporate income tax (tk). The tax base should be the net operating surplus. Because π is aggregated with fixed capital in the model, the tax base should also be modified - it should be the gross instead of the net operating surplus. This also requires that the official tax rate is modified in order to get the proper tax revenue from the corporate income tax.

Demand on capital DK_i is specified from the CES unit cost function (1):

$$DK_i = dk0_i \left(\frac{\mathtt{PLK}_i}{\mathtt{PKE}_i} \right)^{\sigma_i^{LK}} \left(\frac{\mathtt{PKE}_i * pk0}{PK(1 + tk)} \right)^{\sigma_i^{KE}} \frac{N_i}{n0_i}$$
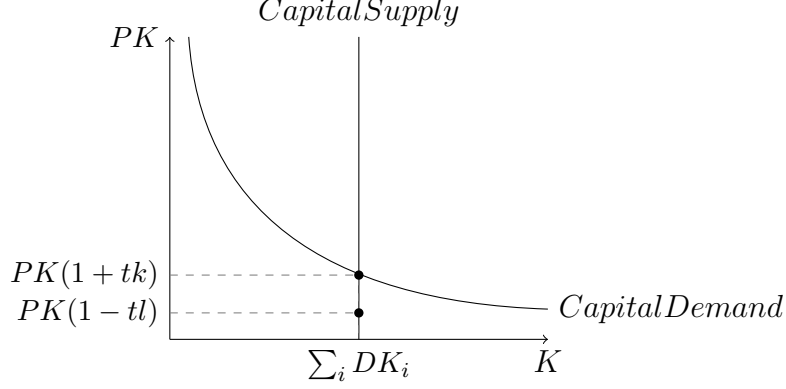
Figure 2: Capital market

where $pk0$ is the benchmark price of capital, σ_i^{KE} is the elasticity of substitution parameter between capital and energy in sector i. These parameters should be relatively small when capital supply is fixed. The capital is supplied by the households, thus the capital income as well as the labor income is subject to the personal income tax tl.

Energy market

The intermediate energy demand is divided into feedstocks and fuels. The feedstocks are energy goods and service (eg. heating), which enter the material aggregate using Leontief function. The fuels are energy goods and services (eg. coal) which enter the factors aggregate through a CES function. This distinction between different types of energy goods and services is essential in order to distinguish the sources of air pollutions. Thus the energy market (en) is defined as a market for gas, coal, biomass, other fuels, and electricity. The market for heating is classified as a non-energy market.

The consumption of energy factors requires the payment of the price PA_{en} and the emission charge $te_{en,i}$. The tax base is the quantity (not the value) of energy consumed (Figure 5). Each energy factor enters the nested production function at a different stage of the nest (Figure 1). For example, the demand for electricity is described by the following formula:

$$DE_{en,i} = de0_{en,i} \left(\frac{\mathtt{PLK}_i}{\mathtt{PKE}_i}\right)^{\sigma_i^{LK}} \left(\frac{\mathtt{PKE}_i}{\mathtt{PEF}_i}\right)^{\sigma_i^{KE}} \left(\frac{\mathtt{PEF}_i * pe0_{en,i}}{PA_{en} + te_{en,i} * \mathtt{PNUM}}\right)^{\sigma_i^{EF}} \frac{N_i}{n0_i}$$

where $DE_{en,i}$ is the demand for energy factor en (electricity, in our example) per sector i, $\mathtt{PEF}_i$ is the implicit price of electricity in the output price of sector i, $pe0_{en,i}$ is the benchmark price of energy in sector i, σ_i^{EF} is the elasticity of substitution between electricity and petroleum products in sector i.

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Energy supply is endogenously determined by the production function in the same way as for other goods in the model. This means that the energy sectors have a double role. On the one side they enter as production factors (demand side), and on the other - as production sectors (supply side). Market clearing condition requires that the supply (including imported energy) equals demand (including private and public consumption).

Zero-profit condition

A zero profit condition is imposed on each sector under constant returns to scale:

$$PN_i * N_i \leq \sum_j PA_j * ID_{j,i} + PL(1+sp)DL_i + PK(1+tk)DK_i + \sum_{en}(PA_{en} + te_{en,i} * \texttt{PNUM})DE_{en,i}$$

where PN_i is the producer price of output i, PA_i is the seller price of product i. The right hand side represents the total cost TC_i for the given output level. The sector's objective is to minimize the total cost:

$$\min TC_i \quad \text{s.t.} \quad f(ID_{j,i}, g(DL_i(DK_i(DE_{E,i}(DE_{F,i}(DE_{G,i}(DE_{C,i}, DE_{B,i})))))))) \geq N_i$$

where $f(.)$ is a Leontief production function, $g(.)$ is a nested CES production function. The conditional demand functions $(ID_{j,i}, DL_i, DK_i, DE_{en,i})$ represent the demands conditional on the output level N_i being produced. Thus there is no way to produce the same amounts of outputs at a lower total cost.

CONSUMPTION

The final domestic demand is represented by the households and the government in order to distinguish between private and public consumption. There is only one representative household in the model. All households in the economy have been aggregated into one household, so no distribution analysis is possible. Investments together with stocks are part of the exogenous demand.

Households

The firm's profits, defined as the gross operating surplus, are redistributed to households. The households also receive a lump-sum transfer from the government:

$$YH = (1-tl)\left(PL(1-sl)(ls-U) + PK * ks - \sum_i PA_i(1+tva_i)inv0_i\right) + \texttt{PNUM*dtax}$$

where YH is the household's disposable income, tva_i is the value added tax rate per commodity i, $inv0_i$ is the exogenous demand on investments, `dtax` are the net nominal transfers including social security benefits (see section Macro closure for details). Consistent with the standard neoclassical assumption, consumers maximize their utility UH subject to a budget constraint:

$$\max UH = \prod_i \left(HD_i - \gamma_i\right)^{\beta_i}$$

$$\text{s.t. } PA_i(1 + tva_i)HD_i \leq YH$$

where HD_i is the household demand for commodity i, γ_i is the subsistence demand for commodity i, β_i are marginal budget shares with $\sum_i \beta_i = 1$ and $0 < \beta_i < 1$. This is a Stone-Geary utility function with quasi-homothetic preferences. The consumers allocate the residual income $(YH - \sum_j PA_j(1 + tva_j)\gamma_j)$ in fixed proportion β_i:

$$HD_i = \gamma_i + \frac{\beta_i}{PA_i(1 + tva_i)}\left(YH - \sum_j PA_j(1 + tva_j)\gamma_j\right)$$

This demand function is a linear function of income and prices and is known as the Linear Expenditure System (LES). It allows for some flexibility in income elasticities η_i: LES is an appropriate model for necessity and superior goods, but not inferior goods. Taking into account all the limitations of this function, it is unlikely to hold across all commodities or consumers. Thus LES provides a more realistic model when the level of aggregation is relatively high, as in our model where we have 1 household and 19 goods.

In order to calibrate this function, we need to ensure the β's add up to unity. Using the definition of the average budget share θ_i^h, the following relation holds: $1 = \sum_i \eta_i * \theta_i^h$. The calibrated income elasticity $(\hat{\eta}_i)$ should satisfy the following condition:

$$\hat{\eta}_i = \frac{\eta_i}{\sum_j \eta_j * \theta_j^h}$$

The calibrated marginal propensity to consume depends on the income elasticity and on the average propensity to consume: $\beta_i = \hat{\eta}_i * \theta_i^h$. Restricting β_i to a constant implies a linear Engel curve.

Government

The government collects taxes, makes and receives transfer payments, and purchases goods and services. Public consumption GD_i is described by the Leontief function,

because there is no evidence that government consumption is flexible:

$$GD_i = gd0_i \frac{YG}{\sum_j PA_j(1 + tva_j)gd0_j}$$

where $gd0_i$ is the benchmark public consumption of product i, YG is the government disposable income:

$$YG = \sum_i gd0_i * PA_i(1 + tva_i)$$

In order to capture the implications of a new environmental policy on the efficiency of public fund raising, the model incorporates the following features of the Czech tax system:

- Value added tax: $VAT = \sum_i tva_i * PA_i(HD_i + GD_i + inv0_i)$, where tva_i is a VAT rate. The tax paid by firms is defined with other net taxes on products.

- Excise tax: $EXT = \sum_i tx_i * \mathtt{PNUM} * A_i$, where tx_i is the excise tax rate, A_i is the market supply per good i. This is the tax on products including the energy tax.

- Other net taxes on products: $OPT = \sum_i ta_i * PA_i * A_i$, where ta_i is the cumulative tax rate for other taxes on products less subsidies.

- Social security: $SSC = \sum_i(sp+sl)PL*DL_i$. This is a quasi-tax. Social security benefits go to households through a lump-sum transfer.

- Personal income tax: $PIT = tl\left(\sum_i PL(1 - sl)DL_i + PK * DK_i + PA_i(1 + tva_i)inv0_i\right)$. We assume that the tax is paid on both labour and capital income.

- Capital income tax: $CIT = \sum_i tk * PK * DK_i$. This tax is treated as a capital input tax, i.e. tk affects the zero-profit condition, not the income-balance.

- Emission charges: $EMT = \sum_{en,i} te_{en,i} * \mathtt{PNUM} * DE_{en,i} + \sum_i tp_i * \mathtt{PNUM}(D_i + Z_i)$, where Z_i is export, D_i is production that stays in the country, tp_i emission charge as resulting from non-energy consumption.

- Other net taxes on production: $OT = \sum_i tn_i(PD_i * D_i + Z_i * ER * pw_i)$, where tn_i is a cumulative tax rate for other taxes on production less subsidies, PD_i is a price index for domestically-consumed local goods, pw_i is the world price parameter, ER is an exchange rate.

The government deficit is one of the three macro balances and we will discuss it in the section Macro closure. No utility function is defined for the government, because there is no economic interpretation for government welfare.
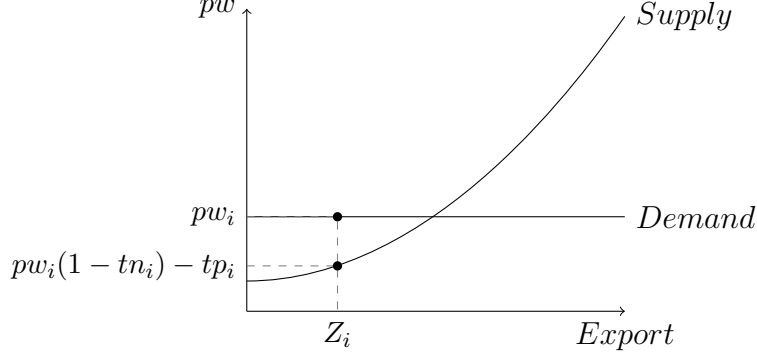
Figure 3: Foreign market for exported products from the Czech Republic

TRADE

The model describes a small open economy, i.e. with infinitely elastic both world export demand and import supply curves. The world price (pw_i) is a parameter in the model, because the Czech economy as a small economy does not have a market power in the world markets. This means that there is neither an explicit world export demand function nor world import supply function.

A domestic firm produces a composite commodity (N_i) that can be exported (Z_i) or sold in the domestic market (D_i). Rather than to assume a rigid dichotomy between tradable and nontradable goods, producers are viewed as producing a differentiated product for domestic and international markets. Their problem is to choose the combination of domestic and international products that minimizes costs. Thus the export supply is represented by a constant elasticity of transformation (CET) function in order to show the relationship between markets destination. The elasticity of transformation σ_i^z shows the degree of transformability of N_i between the supply on foreign markets

$$Z_i = z0_i \left(\frac{pw_i * ER(1 - tn_i) - tp_i * \texttt{PNUM}}{PDZ_i} \right)^{\sigma_i^Z} \frac{N_i}{n0_i} \qquad (2)$$

and the supply on domestic markets

$$D_i = d0_i \left(\frac{PD_i(1 - tn_i) - tp_i * \texttt{PNUM}}{PDZ_i} \right)^{\sigma_i^Z} \frac{N_i}{n0_i}$$

where PDZ_i is the composite transformation price, $z0_i$ is the benchmark export of output i, $d0_i$ is the benchmark domestic product supplied on domestic markets, ER is an exchange rate. The price of exported goods is determined by the world price level only (Figure 3), but the price of D_i depends on both the domestic and the world price (Figure 4).
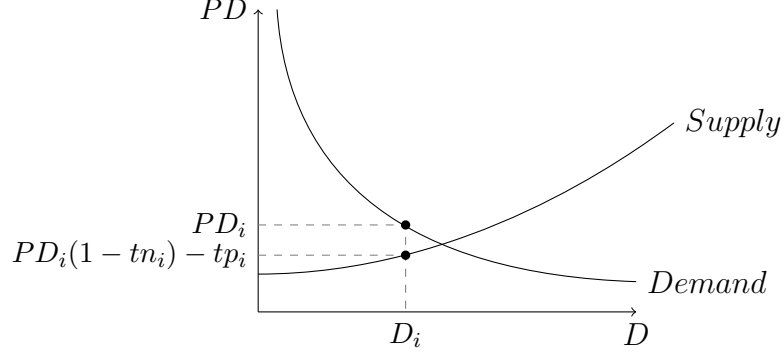
Figure 4: The Czech market for domestic products

The exchange rate is neither the price of the foreign exchange nor a signal to agents, because the model contains no assets or money. It is a 'macro' variable (with units of domestic currency per unit of foreign currency) that equilibrates the exogenous trade balance, rather than a financial variable. Thus there is an implicit functional relationship between the exchange rate and trade balance. Changes in the exchange rate work only by influencing the relative prices of traded and non-traded goods on domestic markets (affecting the export supply and the import demand). Increasing foreign savings yields an appreciation of the exchange rate (the price of non-traded goods rises relative to the price of traded goods). Exports fall (as producers shift production toward domestic markets) and imports rise (as consumers shift demand in favor of imports) bringing the trade balance into equilibrium with a new, higher exogenous level of foreign savings.

In order to avoid over-specialization that occurs in neoclassical models with homogenous products, we use the Armington assumption to define demand on imported products M_i:

$$M_i = m0_i \left(\frac{PDM_i}{pw_i * ER} \right)^{\sigma_i^M} \frac{A_i}{a0_i}$$

where PDM_i is the price for the Armington composite good i, A_i represents the supply of product i, $m0_i$ are the benchmark imports of product i, and σ_i^m is the elasticity of substitution between the demand for imported and domestic products.

Because products are differentiated by country (the Czech Republic and the rest of the world), the 'law of one price' does not hold. Each sector as whole can be a price-maker (i.e. $PD_i > pw_i * ER$) but the specific producer can only be a price-taker. In case of a lack of foreign corresponding goods, the domestic producers are independent, to the extent that they are not limited by the world price but only by the consumers budgets. Although the greater the difference between the foreign price and the domestic price, the lower the sales for the domestic producers.

14

Domestic output net of exports (D_i) should be equal to the demand for domestic output as shown on Figure 4. The shape of the supply curve for domestic products depends on elasticities (substitution, transformation, Armington). The higher the elasticities, the more horizontal is the supply curve.

Both D_i and Z_i are subject to taxation. We assume that the output taxes (tp_i and tn_i) are levied on producers. Thus PD_i represents the gross price index for domestically-sold local goods (before taxes on production). There are neither export quotas nor import tariffs in the model (free trade), because the actual rates were relatively small in 2005 for the Czech economy. Thus c.i.f import prices are fixed and equal to f.o.b. export prices.

The supply (A_i) on the domestic market includes both imported (M_i) and domestic products (DA_i). This trade is also subject to taxation. We assume that the excise taxes (tx_i) and other taxes on products (ta_i) are applied directly on sellers, but VAT and some emission charges are applied on buyers. Thus PA_i represents the price for domestically-consumed both imported and local goods net of taxes on products. This is shown on Figure 5. Market clearance requires that the difference between supply and demand is non-negative for all goods and factors:

$$A_i \geq \sum_j ID_{j,i} + \sum_{en} DE_{en,i} + HD_i + GD_i + inv0_i$$

The demand side of this trade is defined by domestic consumers, but supply is defined by domestic and foreign producers. This means that taxes on products affect directly imported goods, but not exported goods. The price on the domestic market is determined through the arbitrage condition that shows the relationship between the seller price and the Armington price:

$$(PA_i(1 - ta_i) - tx_i * \mathtt{PNUM})A_i \leq PD_i * DA_i + pw_i * ER * M_i$$

Thus, a partial insulation of the domestic price system from changes in world prices is possible through the Armington assumption. Implicit market power depends on the Armington elasticity of substitution.

ENVIRONMENT

Producers and consumers alike are responsible for air pollution emission. Households are responsible for emissions created due to energy consumption HD_{en}. Producers can create pollution both through the energy consumption $DE_{en,j}$ and through the production process N_j. We ignore the emissions created through the public consumption and investment processes.

Total emissions may fall as a result of (i) reduced production of the polluting good, (ii)
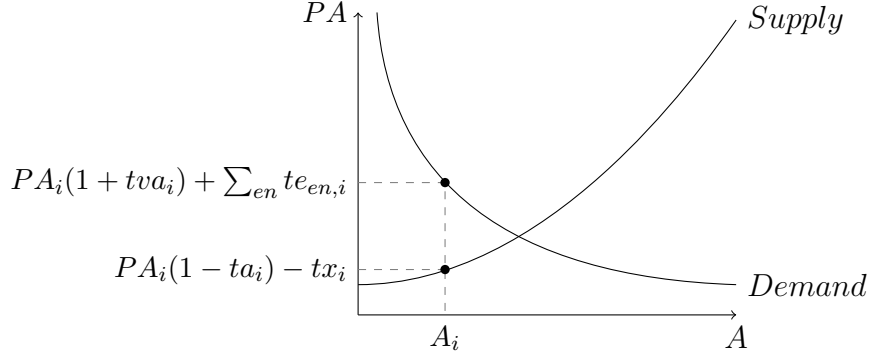
Figure 5: The Czech market for domestic and imported products

substitution with cleaner inputs, i.e. reduced demand on polluting goods, (iii) increased abatement activity. The possibility of abatement is available only for producers and it operates with two inputs: capital and fixed technical potential. The potential to reduce pollution through technical abatement activities provides an upper bound on the abatement. The remaining part of pollution can be reduced only through decreasing the economic activity. When abatement capacity is in fixed supply, a constant returns to scale production function exhibits decreasing returns to scale in the variable input (capital).

We consider the following instruments for achieving an emissions reduction: emission charges t_{em} or other taxes applied on polluting goods (eg. excise tax tx_i). If the government decides to tax the polluting goods directly as an output tax tn_i, then we avoid the taxation of clean goods. Under this regulatory scheme, firms will never abate their emissions, because the tax is levied on the amount of output of polluting goods and this is independent of the abatement expenditures by firms. A similar interpretation can be applied for the excise tax.

Implementation of emission charges means that firms will the bear abatement cost (more energy efficient production or less pollution intensive inputs) and will pay the emission charges on the remaining emissions per unit of output. The abatement cost shifts the supply curve upward. The net effect on consumer surplus of the emission charges will be always negative. The net effect on producer surplus will depend on the abatement possibilities and on the own-price elasticities. When the sector is very capital intensive, the elasticity of supply will be small and this sector will have to absorb a significant share of the increase in marginal cost. The total effect of t_{em} is a reduced output level N_i in addition to a reduction in emissions.

If the abatement technologies are available, then sectors have a choice either to abate or to pay the emissions charges. We have taken the data for abatement cost from the bottom-up model GAINS. In order to incorporate the bottom-up technologies directly into our CGE model, a step function is applied. This means that we use activity

16

analysis to capture abatement possibilities by Leontief technologies that are active or inactive in equilibrium, depending on their probability. The lack of data for all pollutions forced us to apply the abatement technologies only for SO_2, NOx, and PM, i.e. there are no abatement possibilities for CO_2, CO, and VOC. We assume also a zero production level for the abatement sector in the benchmark equilibrium because no data are available.

MACRO CLOSURE

The introduction of the actor 'world' rises the problem of the balance of trade. The simplest solution is to assume that the trade balance is exogenous. The resulting flow of funds are foreign savings. The trade balance can be seen as simply the income-expenditure constraint of the new actor. The 'world' does not appear to be an optimizing entity in any sense, but simply demands and supplies traded goods at the world prices.

Three macro balances should be considered with any CGE model: private savings by households, public savings by government, and foreign savings. The saving-investment account implies that the savings from various sources should be spend on capital goods (investment). Given that IOT is balanced, determining two of the macro balances necessarily determines the third.

Treating the balance of trade ca as exogenous means that the budget constraint of one actor (for example, the government) should include this exogenous transfer:

$$YG = tax - ca * ER - \texttt{dtax} * \texttt{PNUM}$$

where tax means the government revenue from taxes (see section Government), $\texttt{dtax}$ are the net transfers to households. The last parameter helps to deal with public and private savings, i.e. we split the savings between the government and households. Thus a foreign closure is obtained in our model through the fixed trade balance constraint, but the government and households closures are reached through fixed transfers.

An economic equilibrium consists of five conditions: market clearance, zero-profit, income balance, irreversibility, and free disposal. All these conditions are applied in our model.

IV. Simulation analysis

We present simulation results for the new tax rates that Czech government is going to implement before 2016. The results for other scenarios are treated as a part of sensitivity analysis. The BAU scenario corresponds to our benchmark equilibrium.

SCENARIOS

The benchmark trade balance is positive for the Czech economy, but it will be changed in the scenarios endogenously because according to Walras' law we may drop one equation. No changes in productivities or elasticities are considered relative to the benchmark level. We have assumed a constant level of elasticities of substitution across the sectors due to the lack of estimated data: $\sigma_i^{LK} = 0.2$, $\sigma_i^{KE} = 0.2$, $\sigma_i^{EF} = 0.5$, $\sigma_i^{FG} = 0.7$, $\sigma_i^{GC} = 0.8$, $\sigma_i^{CB} = 0.81$. Also a constant rate across the sectors is assumed for the Armington elasticities and the elasticity of transformation. When the elasticity of transformation is relatively high, there is a little price differention between domestic and international markets. If PD_i goes down a little bit relative to $(pw_i * ER)$, it will result in large changes in the allocation of production to export versus domestic absorptions, because of a high degree of transformability. We have assumed $\sigma_i^z = 4$ and $\sigma_i^m = 4$ for all sectors, except the gas sector, where $\sigma_G^m = 20$. The Czech economy can be considered as a price-taker in the gas sector because 96% of the supply depends on imports.

The values of income elasticities are based on estimations by Scasny (2006). There is one good, natural gas, that households do not consume directly. All other products are normal goods and are appropriate for LES function. The level of the unemployment elasticity of wage ($\mu = 0.1$) is based on estimation by Blanchflower (2001). Our sensitivity analysis shows that the model is robust with respect to the level of this elasticity but it is sensitive to the elasticities of substitution. The cost of environmental policy will be lower, the higher the values of elasticities of substitution.

All tax rates are kept at the benchmark level in the BAU scenario. Effective tax rates are applied for VAT and capital tax ($tk = 10\%$) in order to maintain consistently with the data of IOT and the National Accounts. The tax base for personal income tax $tl = 10.2\%$ is both the gross wage adjusted by the social security contribution and the capital income adjusted by investments (otherwise PIT is overrated). The benchmark rates for payroll taxes are $sl = 12.5\%$ and $sp = 32.5\%$. Excise tax tx_i, according to the official rates, is only applied on manufactured goods (1.7%), food (3%), and on petroleum products (49%). It is applied directly on sellers in the model, but it may also affect buyers, depending on the price elasticities. Other net taxes on both products ta_i (including VAT paid by firms) and production tn_i, are defined as residuals.

Emissions charges are applied only on stationary sources of production. This means that mobile sources and households' emission are free of charge according to the Czech environmental policy. The following rates are implemented in the Czech crowns CZK per tonne of pollutant[7]:

$$t_{SO_2} = 1000 \quad t_{PM} = 3000 \quad t_{CO} = 600$$
$$t_{NO_x} = 800 \quad t_{VOC} = 2000 \quad t_{CO_2} = 0$$

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[7]The exchange rate in 2005 was 1 EURO = 30 CZK

Table 2: Percentage change in the emission charge rates (real term) in the scenarios relative to the benchmark level

Pollutant	BAU	I	II	III	IV	V	VI	VII
PM	0	19	91	153	214	272	329	746
SO2	0	19	91	153	214	272	329	746
NOx	0	17	94	149	214	265	326	742
VOC	0	19	91	153	214	272	329	746
CO	0	-	-	-	-	-	-	-
CO2 [CZK/t]	0	500	603	619	633	644	655	669

We consider seven scenarios with the new emission charge rates based on the proposition of the Czech Ministry of Environment in the "Air Quality Act 2009". The proposition assumes to replace the CO tax with a CO_2 tax, to exclude non-energy emission from CO_2 tax, and to increase rates according to Table 2. Original time-path, proposed by the Ministry, assumes that scenario I will be implemented in 2015, scenario II - 2016, etc. However, our model is static and we implement all scenarios for only one period. The goal of our study is not to predict how the Czech economy will look like in the future, but to predict the reaction of markets once the new environmental policy is implemented, assuming the state of the economy in 2005.

All prices in the model are expressed in nominal 2005 level and unit normalization is applied following the Harberger convention. The model considers neutrality of money, but in order to take into account a price changes within the scenarios simulation, we use the Laspeyres price index PNUM, to obtain real prices:

$$\texttt{PNUM} = \frac{\sum_i PA_i(1 + tva_i)hd0_i}{\sum_i ph0_i * hd0_i}$$

where $hd0_i$ is the benchmark households demand on product i, $ph0_i$ is the benchmark gross price, tva_i is the VAT rate, PA_i is the net price. All prices in the model are nominal until we divide them by PNUM. Thus the quantity taxes ($te_{en,j}$, tp_i tx_i) are multiplied by the price index in order to take account of possible price changes in the economy. No inflation occurs because the model can only determine relative prices. We capture price changes via a price index, and not the price of money (inflation).

The new nominal charge rates for pollutants, proposed by the Czech Ministry of Environment, were deflated by CPI in order to express the rates in 2005 price level as shown in Table 2. The index was estimated by Scasny et al. (2009).
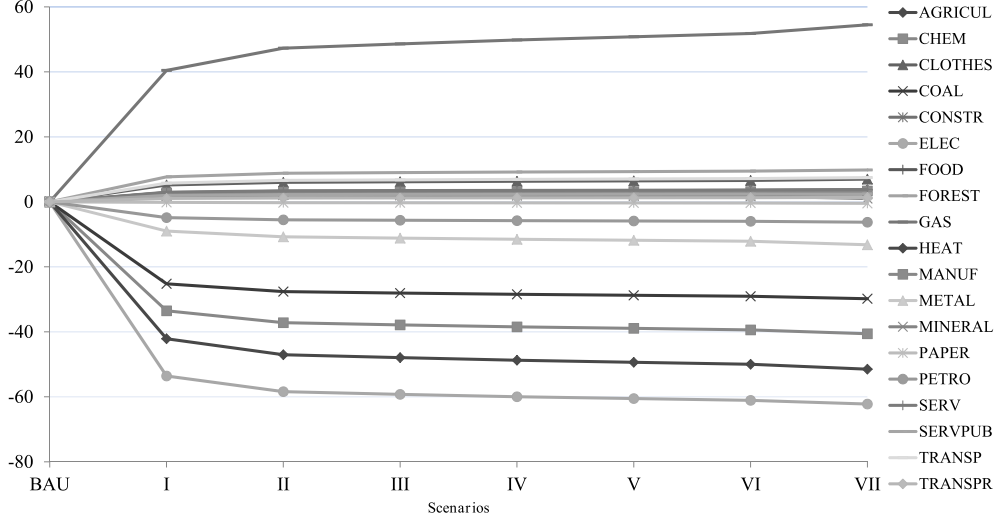
Figure 6: Exports relative to BAU scenario [%]

RESULTS

The main polluting sector in the Czech economy is electricity production with over 40% of total air pollution. It contributes little to international trade (over 10% of the domestically produced electricity is exported and less than 5% of supply is imported). Other polluting sectors are heating, metallurgy, mineral, chemical, and road transportation. The heating is a completely local product, unlike the chemicals where over 70% of production is exported and 80% of supply is imported. The metal sector is also orientated towards foreign trade with over 50% of contribution in both export and import.

The contribution of international trade in the pollution intensive products to GDP is below 18%. The magnitude of the competitiveness effects of higher environmental taxation depends, among other things, on this contribution. Let us see how the results look like. We present the results relative to BAU. For the numéraire we choose the exchange rate. The choice of a numéraire is a reporting issue and has no implications for the results, because only relative prices are determined in CGE models. The one equation is redundant in the model, in accordance with the Walras' law because we have the same number of variables as equations. The trade balance equation is dropped and the fixed exchange rate helps to achieve endogenous trade balance.

Figures 6 shows the results for exports. There is a considerable increase in exports of gas-oil. This is the sector of natural gas and crude oil extraction and it depends completely on international market, because 97% of supply is imported. Thus, a huge increase of export is determined by a very small share (below 0.05%) of this sector in total exports. The positive effect on exports is also for biomass, manufacture, clothes, food, agriculture, other transportation, and services. None of these sectors are pollution
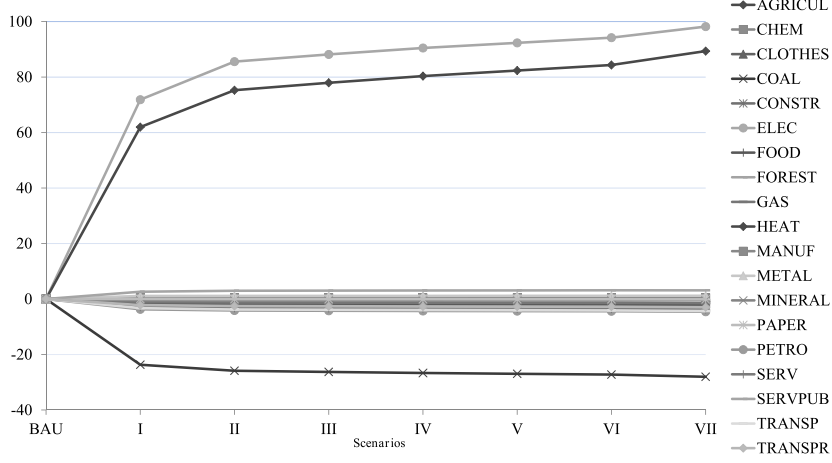
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Figure 7: Import relative to BAU scenario [%]

intensive. The details can be seen in Figure 8, where we ignore the sectors with very low shares in international trade.

There is an up to 2% increase in exports of minerals and road transportation sectors. Both sectors are pollution intensive. The exports decrease for other pollution intensive sector, as expected. Why do exports increase for minerals and road transport? The output of the road transportation becomes constant after new emission charges are implemented, while the output of minerals increases by 1% in the first scenario. The reason is the price. The new tax rates do not change the prices of these two products, but they affect the price of other pollution intensive products (electricity, heating, metal, and chemicals). Figure 9 shows the relationship between domestic and world prices in the first scenario.

The exports of other pollution intensive products decrease as expected. The export of coal and petroleum products also decreases because these two products are directly related to pollution emission. It is determined by a fall in demand as combustion of oil and coal generates pollution. However, the price of these two products would not change significantly as shown on Figure 9. This is the gross price of the final goods, i.e. before taxes on production are applied (Figure 4). Once the new rates of emission taxes are applied, the supply of exported goods goes down according to formula (2).

The situation of imported goods looks interesting (Figure 7). There are two significant increases - for electricity and for heating. We may ignore the imports of heating as discussed before. It is also currently difficult to import electricity, but the possibilities are much greater than in the case of heating. When the price of the domestic product increases relative to the world price (Figure 9), imports also increase. However, the imports of electricity are only 4% for BAU scenario and it is only double as much in the last scenario.

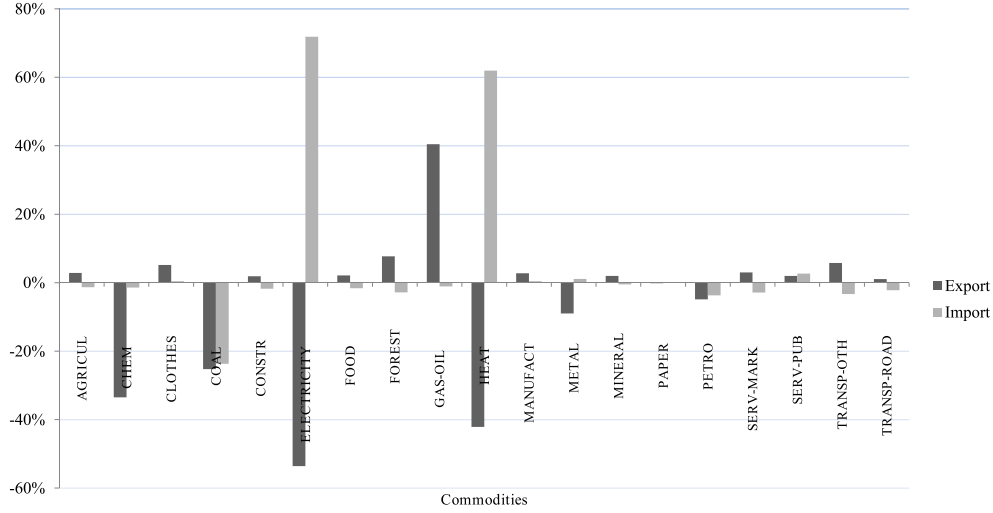Some small positive effect on imports is also observed for metals. This is one of the

Figure 8: The relationship between exports and imports in scenario I (relative to scenario BAU)

pollution intensive goods, along with electricity and heating. The imports of other pollution intensive commodities (minerals, chemicals, road transport) slightly decreases. A significant decrease is observed for coal, as the demand for coal goes down sharply. On the other hand, the import of biomass (forest), other transport, market service, natural gas and crude oil goes down in a fashion similar to petroleum products. Combustion of petroleum products creates pollution and it is rather obvious that the demand for
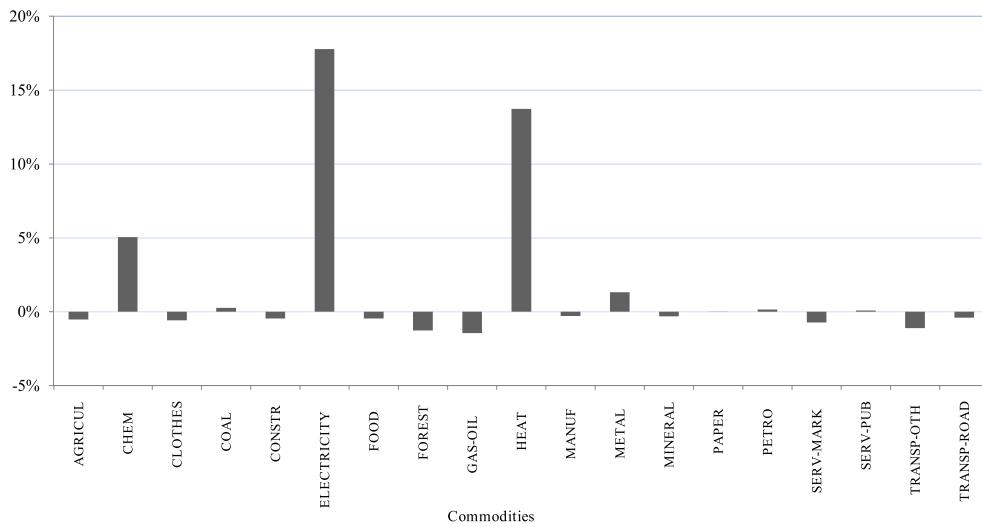

Figure 9: Domestic price (PD_i) relative to world price ($pw_i * ER$) in the scenario I

oil goes down. But why would the import of biomass or services decrease? Figure 9 explains it: the relative domestic price goes down and the domestic market becomes less attractive for foreign producers.

Finally, let us see how the macro indicators change. Figure 10 shows that the new tax rates have a negative effect on the trade balance (a decrease of 10% in scenario I) but a trade surplus would still be reached. Most of the sectors, including pollution intensive production of minerals and road transportation, however, increase the trade balance (especially clothes, market service and non-road transportation). A considerable decrease in the trade balance in other pollution intensive sectors and coal implies that the overall effect is negative for the economy. On the other hand, there is no overall effect on output even if some sectors considerably decrease production, because the biggest sector (manufacturing) increases production by at least 2%. The main losers are the chemical sector (-30%), coal (-25%) and electricity (-15%). Higher government revenue will allow for an increase in public expenditures. Government can redistribute this additional revenue to poor households and some sectors in the initial period. GDP may decrease up to 0.5% and consumer price index may increase up to 0.5%. Generally, the increase in emission charges should not considerably affect the competitiveness of the Czech Republic.

V. Conclusion

The goal of the paper was the analysis of international trade of the Czech Republic with the rest of the world after the new emission tax rates are applied. We are not attempting to predict how the Czech economy will look like in a future, only how the planed environmental policy would affect the economy. A number of assumptions is considered: the structure of economy will look like in 2005, no intra-sector competition, constant
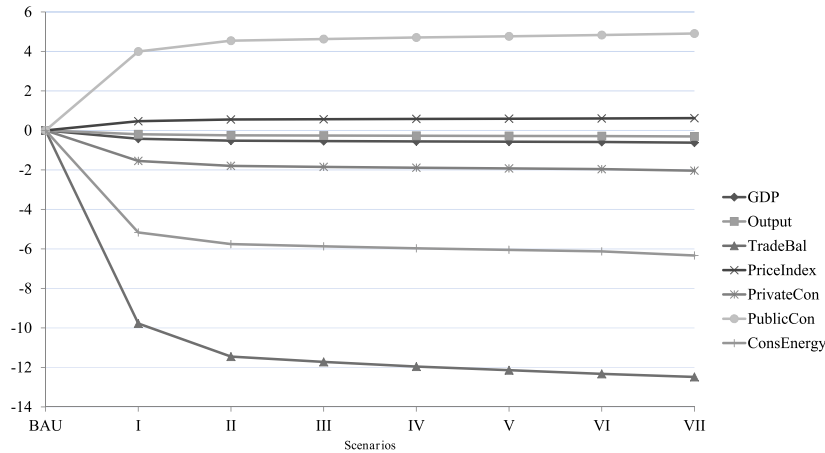

Figure 10: Macro indicators relative to BAU scenario [%]

returns to scale technologies for 19 sectors, and limited mobility for some production factors. On the other hand, we include endogenous unemployment, a decreasing returns technology for the abatement sector, energy production factors in addition to primal factors, and we try to closely replicate the tax system.

We have presented the detailed description of the model in order to help the reader understand the results better. All equations are defined in a calibrated share form that allows us to speed up the calibration process. The description of the capital market reveals how CGE models deal with profit. Calibration process of the LES function shows how to ensure a unit marginal budget share. A distinction between taxes on products and taxes on production is essential for a proper representation of a fiscal policy.

The model is used for analysis of a cost-effective response to a pre-determinant policy target. The simulation of the environmental policy for the Czech economy shows that the increase in emission charges should not considerably affect the competitiveness of the country. The main polluting sector (electricity) participates on a minor scale in international trade. The contribution of international trade in all pollution intensive products to GDP is below 18%. Sectors like biomass, manufacture, clothes, food, agriculture, non-road transportation, and market service will even increase export. But some pollution intensive sectors (minerals and road transportation) will increase export too.

Energy consumption will decrease, as expected. Producers would substitute emission intensive production factors (like coal) with other factors. Coal is the only sector where both the exports and the imports will go down significantly. Some decrease in imports can be expected in petroleum products, non-road transportation, and services. The total effect on the trade balance will be negative, but no trade deficit is expected. Most of the sectors will benefit, especially services, non-road transportation, and clothes. There is a slight decrease in GDP (up to 0.5%) and a similar increase in the consumer price index, but the final consumption will decrease by 2%. This is the price tag on the cleaner environment. The purpose of environmental taxes is not just an increase in government revenue but also a decrease in pollution emission. Taking into account that the government revenues will go up, the additional revenue can be spent on subsidies for some sectors, which would allow to keep international competitiveness unchanged. It will also create an incentive to invest in energy-saving technologies.

The general equilibrium approach provides a consistent and comprehensive framework for studying price-dependent interactions between markets, but it also has many limitations. The central assumptions drive the results. We have tried to construct our model in a way that would allow us to capture the key entities and relationships of the policy issues at hand. The model can be improved in the future by applying bottom-up technologies for energy sectors similar to the abatement sector, if an engineering model is available.

REFERENCES

ALTEMEYER-BARTSCHER, M., D. T. G. RUBBELKE, AND E. SHESHINSKI (2010): "Environmental Protection and the Private Provision of International Public Goods," *Economica*, 77, 775–784.

BLANCHFLOWER, D. (2001): "Unemployment, Well-Being and Wage Curves in Eastern and Central Europe," *Journal of Japanese and International Economies*, 15, 364–402.

BLANCHFLOWER, D. G., AND J. OSWALD (1995): "An introduction to the wage curve," *Journal of Economic Persepctives*, 9, 153–167.

BOEHRINGER, C., K. CONRAD, AND A. LOSCHEL (2003): "Carbon Taxes and Joint Implementation. An Applied General Equilibrium Analysis for Germany and India," *Environmental and Resource Economics*, 24, 49–76.

BOEHRINGER, C., T. F. RUTHERFORD, AND W. WIEGARD (2003): "Computable general equilibrium analysis: Opening a Black Box," Discussion Paper 56, Centre for European Economic Research (ZEW).

BRUHA, J. (2002): "A Green Tax Reform And Unemployment: the Case of the Czech Republic," in *Macromodels 2001*, ed. by W. Welfe, conference proceedings. University of Lodz.

BRUHA, J., AND M. SCASNY (2005): "Environmental Tax Reform Options and Designs for the Czech Republic: Policy and Economic Analysis," in *Critical Issues in Environmental Taxation*, ed. by A. Cavaliere, and H. A. J. Milne, K. Deketelaere, vol. III of *International and Comparative Perspectives*, chap. 17. Oxford University Press.

DYBCZAK, K., D. VONKA, AND N. VAN DER WINDT (2008): "The effect of oil price shocks on the Czech Economy," Working Paper Series 5, Czech National Bank.

E3M-LAB (2008): "The GEM-E3 Model for the European Union," Reference manual, National Technical University of Athens.

EC (2001): "Economic and Environmental Implications of the Use of Environmental Taxes and Charges in the European Union and its Member States," Report, European Commission.

EEA (2008): "Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries," Report 2, European Environment Agency.

Janovskij, I., and M. Rojicek (2004): "CGE Models Applied on new European Union Memebers: case of the Czech Republic," Intermediate international input-output meeting, Free University of Brussels.

Kiuila, O., and J. Sleszynski (2003): "Expected effects of the ecological tax reform for the Polish economy," *Ecological Economics*, 46, 103–120.

Martin, W., and K. N. Skinner (1998): "Resource taxation and sustainibility: A CGE model of the Czech Republic," *Natural Resources Research*, 7, 287–300.

Orrell, D., and P. McSharry (2009): "System economics: Overcoming the pitfalls of forecasting models via a multidisciplinary approach," *International Journal of Forecasting*, 25, 734–743.

Proost, S., and D. van Regemorter (2004): "Climate change policy in European countries and its effects on industry," *Mitigation and Adaptation Strategies for Global Change*, 9, 453–475.

Scasny, M. (2006): "Distributional effects of environmental regulation: Theory and empirical evidence for the Czech Republic," Dissertation, Charles University in Prague.

Scasny, M., V. Pisa, H. Pollitt, and U. Chewpreecha (2009): "Analyzing Macroeconomic Effects of Environmental Taxation in the Czech Republic with the Econometric E3ME Model," *Czech Journal of Economics and Finance*, 59, 460–491.

Wissema, W., and R. Dellink (2007): "AGE Analysis of the Impact of a Carbon Energy Tax on the Irish Economy," *Ecological Economics*, 61, 671–683.