IV Simulation of distributional effects

The main objective of this Section is to assess the distributional welfare effects due to a public intervention that focuses energy taxes.[1] We measure tax progressivity by the marginal Gini Index and the Suits Index. Our measurement of tax changes is performed for an increase in tax on dirty goods, a revenue neutral environmental tax reform and for the overall tax system of the Czech Republic.

The structure of this Section is as follows: Section IV.1 starts with method for distributional effects assessment we use. Then, we describe data and main tax changes involving distributional effects we aim to analysis. Section IV.3 provides measurement of distributional impacts due to financial effects, starting with ex post measurement of the tax changes and the entire tax system during the period 1993—2004, and following with ex ante measurement of distributional effects due to considered tax changes. Last Section IV.4 introduces an innovative approach for an assessment of distributional effects due to changes in environmental quality.

IV.1 Distribution of financial effects

IV.1.1 Simulation method

Using the estimates of price and income elasticities given in Section III, we simulate distributional effects on different household groups due to various marginal energy and transport tax changes. The simulation approach is following: first, we use elasticity estimations to predict household responses and changes in household consumption on and expenditures for taxed goods. Then, we calculate tax paid and thus public revenues before and after tax change. Thirdly, we derive welfare change due to tax change by estimating compensating variations. Having these results allows us to derive a dead-weight loss of tax change as a difference between changes in public revenues and needed compensations that would sustain households welfare unchanged. We also derive a model to predict income effects due to possible revenue recycling via lowering labour taxation and/or a provision of social lump-sum transfers. We predict all of these changes for each individual household. Lastly, we

[1] Increase in tax regressivity due to CO_2 tax is examined for instance by Poterba 1991; Barker and Kohler, 1998. Regressivity of gasoline and miles taxation is worked out by Walls et al., 1994; Kayser, 2000; Sipe and Mendelsohn, 2001; West, 2004; reviews in Dahl and Sterner, 1991 or Espey, 1996.

measure a tax progressivity by two well-know indexes such as the Gini and Suits index.

IV.1.1.1 Direct price effects

Our simulation method can be described as follows. The price change on good *j* is calculated as

$$\Delta P_j = \ln(P_j^1 / P_j^0), \qquad \text{(IV-1)}$$

where $P_j^p = (netP_j^p + \tau_j^{ep}) * VAT_j^p$ presents the consumer price of good *j*, the subscript *p* denotes the regime before (*p=0*) and after a tax change (*p=1*), "*netP*" is the net, before-tax, price, τ^e is the excise tax on energy (unit tax), and *VAT* is the value added tax (ad valorem tax).[2] We assume no price differentiation among the households.

After-change in expenditures of household *k* on the modelled vector of non-durable goods ***j***, i.e. energies, is then approximated by:

$$E_k^1 = \sum_j \left[E_{kj}^0 * (1+\Delta P_j)^{(1+\eta_{jj})} \times \prod_{c \neq j} (1+\Delta P_c)^{\eta_{jc}} \times (1+\Delta Y_k)^{\eta_j^y} \right] \qquad \text{(IV-2)}$$

where E_{kj}^0 is the original total expenditures of household *k* on non-durable good *j* (e.g. electricity), η_{jj} is the own uncompensated (Marshallian) price elasticity for good *j*, and η_{jc} is the uncompensated cross-price elasticity of demand for good *j* on price change of good *c*, *ΔY* is the logarithm of a household total net income change due to a marginal tax change in labour taxation and/or transfers, and η_j^y is the income elasticity of demand on a non-durable good.

Calculation of a change in paid excise taxes follows by considering both excise tax, τ, and value added tax rates and the amounts of goods before and after tax change. We consider also the tax revenue from (changed) VAT on the rest of consumer goods likely being changed due to higher energy taxation. Summing up all changes in excise taxes and VAT paid, we get a change in paid taxes and thus net total additional public

[2] A change in price of heat is calculated differently. Since heat is produced by using gas and/or coal, the heat price depends on the industrial prices of coal and gas. Using the Czech statistics, we assume that heat is produced from coal and gas in the ratio of 3:1. We then estimated a responsiveness of heat price change on change of coal and gas price as high as +0.72, meaning that final price of heat would be increased by 7.2%, if weighted price of gas and coal input increased by 10%.

revenues due to the energy tax change for each household, *$TAXREV_k$*, as follows:

$TAXREV_k$ = Δenergy excise taxes + ΔVAT on energies + ΔVAT on rest of goods (IV-3)

$$TAXREV = \sum_j \left[\left(\frac{E_j^1 \cdot \tau_j^{e1}}{P_j^1} - \frac{E_j^0 \cdot \tau_j^{e0}}{P_j^0} \right) + \left(\frac{E_j^1 \cdot VAT_j^1}{(1+VAT_j^1)} - \frac{E_j^0 \cdot VAT_j^0}{(1+VAT_j^0)} \right) \right] + \left(\frac{(Y^0 - \sum_j E_j^1) \cdot VAT_{rest}^1}{(1+VAT^0)} - \frac{(Y^0 - \sum_j E_j^0) \cdot VAT_{rest}^0}{(1+VAT^0)} \right)$$

One should be aware of the fact that if energy consumption was increased due to higher energy tax, there would be simultaneously lower public revenues from value added tax on the other goods due to lowered consumption of the these goods (considering the budget constraint). It, however, also results in the fact that – assuming VAT on rest of goods unchanged - higher energy taxation based on certain increase in VAT, e.g. on heat, would not yield different magnitudes of changes in additional public revenues if different demand responsiveness and thus elasticities were assumed in the distributional effect simulations; such VAT change would however yield different magnitudes for changes in energy consumption if predicted.

To evaluate welfare impacts due to possible revenue recycling we derive a model to simulate social and health obligatory insurance contributions and direct labour taxes. Our model considers consistently the institutional labour taxation rules in the Czech Republic as enforced in time relevant for our assessment (2004)[3]. Our model allows calculating the social and health obligatory contributions and direct labour taxes paid as by employee and by employer after changes in taxation scheme such as:

- income brackets for labour taxation,
- marginal tax rates set out for each income bracket,
- deductibles affecting tax base, and
- rates for insurance contributions.

Changes in social transfers do enter to our model too.

Combining changes in the household expenditures, received new social transfers, *SOCIAL*, and possible income effects due to change in labour taxation and insurance payments, *TAXLABOR*, we are able to calculate the

[3] Labour factor taxation consists of two parts in the Czech Republic: first part presents a direct labour taxation that is based on progressive taxation scheme consisting three income brackets and four marginal rates. Payable taxes are then calculated from the tax base given as gross salary minus paid obligatory insurance payments and untaxed deductibles related to the employee and his/her children; second part is given by obligatory contributions to the public social and health insurance system paid by employees. These payments are computed as a percentage share of gross salary.

overall impact on household' budget, *HH_BUDGET*, and on the state budget bill, *STATE_BUDGET*, as:

$$HH\_BUDGET_k = (E_k^1 - E_k^0) + \Delta TAXLABOR_k + \Delta SOCIAL_k \qquad \text{(IV-4)}$$

$$STATE\_BUDGET_k = TAXREV_k + \Delta TAXLABOR_k + \Delta SOCIAL_k + (Y_k^1 - Y_k^0) \cdot VAT_{rest}^1 \qquad \text{(IV-5)}$$

where the last term in calculation of total additional revenues of the state budget in eq. IV-5 refers to the revenues from VAT on rest of goods consumed thanks to the net household income (increased due to lower labour taxation and/or social transfers provided).[4]

As already discussed in Section II, social impacts of regulation (e.g. taxation) can be conceptually measured following two approaches: either to estimate additional household expenditures or to estimate certain welfare measure. The welfare measure, particularly compensating or equivalent variation, is more suitable - and consistent with economic theory - approach for the household welfare assessment. On the contrary, the approach based on additional expenditures is more suitable for assessment of household impacts with regard to a change in structure and magnitude of expenditures. It then indicates how a change in final prices can affect consumption of certain goods. The additional expenditures can be also related more closely to financial resources that can be possible used by the households for desirable adaptive measures like investment in more environmentally-friendly durable goods. We therefore simulate the impacts on both of these variables – additional expenditures and compensating variation in our model. The compensating variation is estimated – as already discussed in Section II - as a geometric mean of increased Laspeyers and Paasche price indexes multiplied by original net household expenditures.[5]

If tax revenues were recycled through lowering labour taxes and/or providing lump-sum social transfers, total impact on household welfare would be given as a difference between the compensating variation and change in net household income due to labour taxation cuts and/or social lump-sum transfer provisions. Therefore, the welfare impact and the compensating variation would be the same if no revenues were recycled and social transfers provided.

The difference between the additional budget revenues and the welfare impact is then our measure of dead-weight loss (hereinafter DWL). If the dead-weight loss is positive, there is an economic loss and inefficiency due to a tax change concerned. If the efficiency is applied as a policy criterion,

[4] We do not model change in marginal propensity to savings after marginal (energy) tax changes, implicitly assuming the propensity equals to zero.

[5] To estimate the change in cost-of-living index, we use both Laspeyers and Paasche approaches, whilst both approaches yield very similar results.

possible environmental benefits and employment double dividend should thus be at least as high as the dead-weight loss to get a welfare improving situation. Because we do not model effects on labour supply due to the labour taxation cuts, DWL would be overstated (and equal to DWL as given for the variant without revenue recycling).

We calculate the changes of all reported variables for each household in our sample. Then, we calculate average changes for each household group and income class as described above by using PKOEF variable. Assuming 4.2 million households and weights provided by the Czech Statistical Office, we derive total changes of variables for the entire Czech population too.

IV.1.1.2 Tax progressivity measurement

To measure progressivity or regressivity of the tax system and its changes, we explore concepts of Gini and Suits indexes.

We base our calculation of the Gini index[6] on a measure of the household economic wealth that we define as a ratio of the net household income on the living minimum standards. We follow particularly the approach by Jorgensen and Pedersen (2000), latter also applied by Wier et al. (2005) and consider so called *marginal Gini index*. Progressivity of a marginal tax change is then calculated as a difference between the Gini Index given after tax change and the Gini Index before tax change as calculated for disposable income. Because the Gini index vary between 0 (perfect income equality) and 1 (perfect inequality), positive changes in the marginal Gini index indicate regressive burden of policy measure or regressive actual distribution.

We also apply the second measure of progressivity, the Suits Index (Suits, 1977). The Suits index is calculated analogously to the Gini index with a difference based on comparing accumulated percent of total income (x axis) and accumulated percent of total tax burden (y axis). Formally, the Suits Index can be derived as:

$$S_x = 1 - L_x / K \qquad \text{(IV-6)}$$

and

[6] The Gini index is the area between the line of perfect equality (the diagonal) and the Lorenz curve. In general, the Lorenz curve is a graph that shows, for the bottom *x*% of households, the percentage *y*% of the total income which they have. The percentage of households is plotted on the *x*-axis, the percentage of income on the *y*-axis. Gini measures a percentage of this area on total area lying between the line of perfect equality and the line of perfect inequality. The Gini index can thus vary between 0 for perfect income equality and 1 for perfect inequality.

$$L_x = \int_0^{100} T_x(y)dy \cong \sum_{i=1}^{n} (1/2)\left[T_x(y_i) + T_x(y_{i-1})\right](y_i - y_{i-1}) \qquad \text{(IV-6')}$$

where T_x is a accumulated percent of total tax burden for household group *i* at given tax x, y_i is accumulated percent of total income, i equals to a number of household groups.

The area of *K* is of course the same for all taxes and equals to 5,000 (the area of triangle with side of 100. Then, the Suits index varies from -1 to 1, where a negative number indicates a regressive tax change, a positive Suits index refers to a progressive tax change, while 0 to a flat tax.

The Suits index can however leads to misleading results for a tax reform in which one tax rate is raised and another lowered, just the case of the environmental tax reform (see e.g. West and Williams, 2004). We therefore calculate the effect of the tax reform on the Suits index for the entire tax system, rather then calculating the Suits index for a particular tax change (as e.g. Metcalf, 1999). This approach yields similar outcomes to the index proposed by West and Williams, particularly for a tax system that is approximately flat and a tax reform relatively small relative to the entire tax system (*ibid.*).

We highlight a proper interpretation of such indexes: while the Suits index measure progressivity of taxes paid, i.e. answer the question if the tax payments are distributed equally among the households, the marginal Gini index measure a change in income inequality after tax change. The marginal Gini index therefore do not provide answer on question if certain income distribution is equal, but rather on question in which direction concerned policy intervention (tax changes) affect the original income distribution. More specifically: negative Suits index indicates regressive tax payments, while decrease in the Suits index after tax change indicate an increased regressivity of tax payments; on the other hand, any positive change in the marginal Gini index indicates regressive burden of policy measure, thus increased income regressivity and income inequality.

All of Gini indexes and Suits indexes are calculated using individual HBS data, i.e. i=2,633 adequately ordered and weighted individual households. As in the Suits index as the marginal Gini indexes calculations, we order the households from HBS dataset according to their relative economic power that we measure by a share of household net total incomes on the minimal living-standard officially set out by the authority. Apart from this measurement, we also experiment with total net household incomes and total household expenditures. Their results support those ones given for the first household wealth measurement.

IV.1.2 Data

We use HBS data for the year 2004 excluding those observations that belong to household "energy" group REST having overall 2,633 data. For any aggregation allowing us to provide a prediction for the entire Czech population, we assume 4,200,000 households.

HBS 2004 dataset is relatively comparable regarding the wages volumes[7], while it contains low share of the unemployed (about 2.3% of all economically-active person are unemployed, while the unemployment rate equalled to 10.2% in 2004 (MoF, 2005)). The tax revenues officially reported by the state authorities yielded 133 bln. CZK from labour taxation and 388 bln. CZK from the obligatory payments to social insurance system (MoF, 2005). The insurance payments are paid as by employees (12.5 from gross wage) as by employers (35%); the employees contributed by 93 bln. CZK, 295 bln. CZK were provided by the employers.

HBS data indicates slightly different tax revenues. Weighted labour taxes paid by the employees amount 85 bln. CZK, and the obligatory payments to social and health insurance paid by employees are as high as 99 bln. CZK in HBS 2004 dataset. The reason of difference may lay within the tax system rules that require taxes to be pre-paid that are then in following year balanced. Therefore, we predict taxable bases, the paid taxes and the contributions to social and health insurance systems for each individual in HBS dataset before tax-change as after tax-change rather than directly using reported data in HBS. This ensures a consistency between simulated (additional) public revenues after tax change with the initial data on paid taxes and obligatory contributions (and initial level of public revenues). Results of our wage model simulation, including average data on household expenditures, consumption and paid taxes for the energy goods and motor fuels for each income class are reported in tables AIV-1 to AIV-3 in Appendix.

We consider following parameters of labour taxation:

- three income brackets: 109,200; 218,400; and 331,200 CZK,
- labour tax rates for the brackets: 12%, 19%, 25%, and 32% for the taxable income above 331,200 CZK,
- deductibles for the employee as high as 38 040 CZK, and for one child 25 560 CZK,
- social and health insurance rate of 12.5% paid by the employee and 35% paid by employers; for the self-employed we consider a

[7] While total wages in HBS 2004 dataset weighted by PKOEF amounted of 830 bln. CZK (950 bln. CZK including revenues from business activities), total volume of wages and salaries amounted 887 bln. CZK (according to MoF, 2005), or 907 bln. CZK (according to the Czech Statistical Office data) in the year 2004.

rate of 43.1% and a relevant base considered for the insurance payment as high as 40% of profit.

For those who are not aware of the Czech tax structure and regime including their relevant changes we refer to a special chapter on the Czech tax system enclosed in Appendix.

IV.1.3 Tax Progressivity measurement

IV.1.3.1 Ex post measurement of tax progressivity

Distributional effects due to a public intervention may make an initial distribution of wealth or incomes more even or more unequal. Analyzed distributional effects thus depend on the pre-change level of the income distribution. Our intention here is to assess the distributional effects due to tax regime changes with a special look at those changes that has certain environmental character, particularly of an environmental tax reform (ETR). Such reform would arise from a shift of taxation from labour and capital towards taxes on environmentally hot items.[8]

We measure distributional effects of the components of the entire tax system by two indexes: the Suits index indicates how the tax payment relevant for certain tax component are paid by the households; the marginal Gini index compares income distribution without particular tax introduced and after tax (including its changes) introduced.

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[8] Tax changes relevant for the environmental regulation introduced in the Czech system during the period of 1993 to 2004 is reviewed and analyzed by Brůha and Ščasný (2005a). The most relevant ones in energy taxation present application of standard VAT rate at 22% on electricity, coal and gas, while before taxed by reduced 5% rate, and a slight increase in unit (excise) tax rate for motor fuels in 1995 and 1998 (although their real rates were continuously down-warding up to 2003). Labour tax changes are described in Appendix. More about the concept of environmental tax reform in the Czech Republic see for instance in Ščasný (2002); a fiscal aspect of the Czech proposal on the reform are discussed by Brůha and Ščasný (2005b); Ščasný and Brůha (2003; 2004).
In order to assess the ETR character of tax changes, we may recall the concepts of 'implicit' and 'explicit' Environmental Tax Reform (Brůha and Ščasný, 2005a). While the 'explicit' ETR uses environmental concerns to support the reform, the 'implicit' ETR does not make any reference to environmental protection and is defined simply as a shift of the tax burden from labour/capital into energy or environmental use. The rationale behind the 'implicit' ETR may be modernisation of the tax system or external pressures. Nevertheless, investigation of instances of the 'invisible' ETR yields useful insights on macroeconomic and distributional consequences of explicit reforms. Brůha and Ščasný (2005a) identify such 'invisible' ETR character for the tax changes introduced in the year of 1995, 1998, and 1999. The 'explicit' ETR can be found within the changes of tax regime have been introducing since year 2000. Tax changes documents Figure AIV-6 attached in Appendix.

First we focus on the distributional aspects of the entire Czech tax system: we found that the Czech tax system is slightly progressive during the entire analyzed period of 1993—2004, with the Suits index located around +0.04 level (see Figure IV-1). Contrary to a political rhetoric, the tax system progressivity was increased under governments of right-wing parties (1993—1995), and became more regressive under social-democratic governments (since 2002). Measured by the marginal Gini index, income inequality was lowered during the entire period due to tax changes, mostly up to 1997 (the indexes are around -0.03 level).

Figure IV-1: The Suits Indexes for the entire Czech tax system.

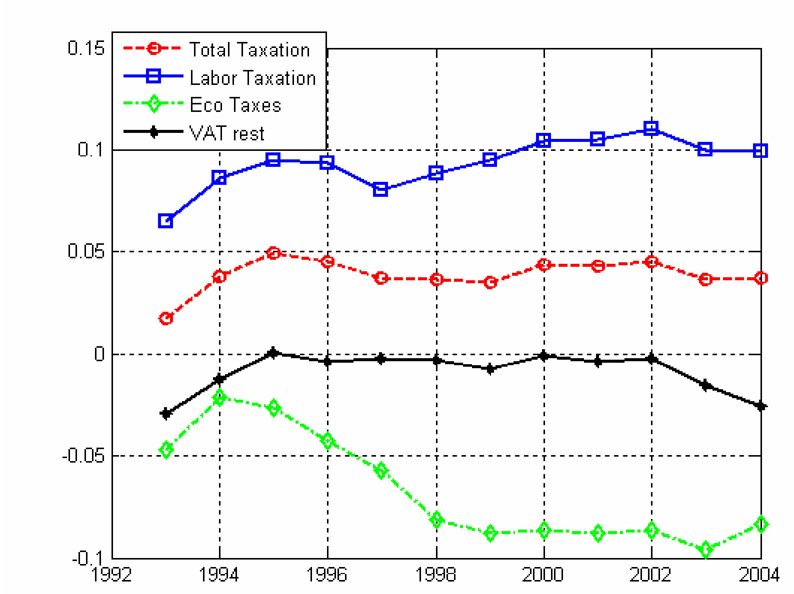
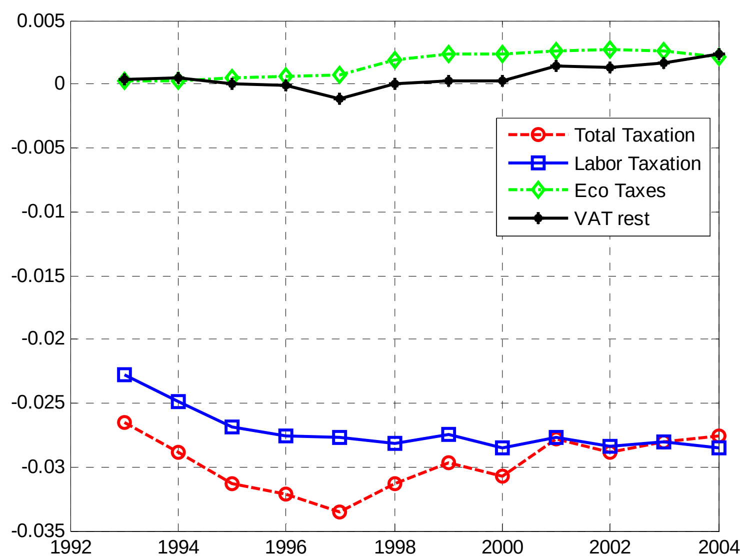


Figure IV-2: The Marginal Gini Indexes for the entire Czech tax system.



Labour taxation is slightly progressive (the Suits indexes are around +0.1), and their progressivity weakened in the mid of nineties (1996—1997) and in the end of considered period. This is confirmed by the marginal Gini indexes that are continuously falling from -0.023 to -0.028.

Taxation of the rest of goods (i.e. VAT on the other than energies and transport services) is rather flat, and it is slightly more progressive at the beginning and slightly regressive in the end of analyzed period.

Environmental taxes — that we define as a sum of excise tax on motor fuels, and VAT levied on energies and motor fuels — are regressive. Their regressivity was even deepened; i.e the Suits index is falling down from -0.02 in 1994 to -0.10 in 2003. Marginal Gini indexes are also continuously growing from zero to +0.003 confirming growing regressivity during that period.

Then, we look more in detail at specific types of environmental taxes. Excise tax (ET) on motor fuels is regressive. The marginal Gini indexes indicate its growing regressivity especially during 1995—1999. As we can see in Tables AIV-5 and AIV-6 in Appendix, it was just years when the tax rate on diesel and petrol were significantly increased. Due to VAT design, VAT on motor fuels is also regressive and indicates similar tendency as excise tax. We confirm decrease in tax regressivity and in income inequalities due to a decrease in VAT rate on motor fuels introduced in the year 2004.

VAT on energies is still the most regressive tax among all analyzed with the Suits indexes at -0.17 level. Increase in VAT rates for residential energies, as introduced on January 1998, also leads to an increase in tax regressivity for next two years. This tax change also heavily increased income inequality (marginal Gini index jumped up as the most during the entire period). Regressivity of VAT tax on energies has started slightly fall since 2003. VAT on public transport is also regressive, but still lesser than VAT on energies (Suits -0.12). As the share of expenditures on this service is not high, the marginal Gini indexes, although indicating a small regressivity, is close to zero.

Motor fuels taxation has remained to be the least regressive from analysed environmental taxes even after its rates were increased. Regressive character of energy taxation has been enforced by shifting coal, electricity and gas to the standard (higher) VAT rate on January 1998. The overall less regressivity of motor fuel taxation is likely due to a relatively constant share of motor fuel expenditures on total expenditures among the various income classes. Thus, one can expect, the ETR scenario based more strongly on motor fuel taxation would be less susceptible to adverse social effects.

On the other hand, the labour income tax is progressive and its progressivity rose during the period 1996—2002. The explanation is as follows: the real tax allowances remained constant as well as the first three bands of the labour income tax (the fourth band was abolished, but this only influenced a minority of employees – less than 1%), and provided that the wages of high-wage workers rose more rapidly than those of low-wage workers, this resulted in an increase in progressivity.

Figure IV-3: The Suits Indexes for the environmental taxes.

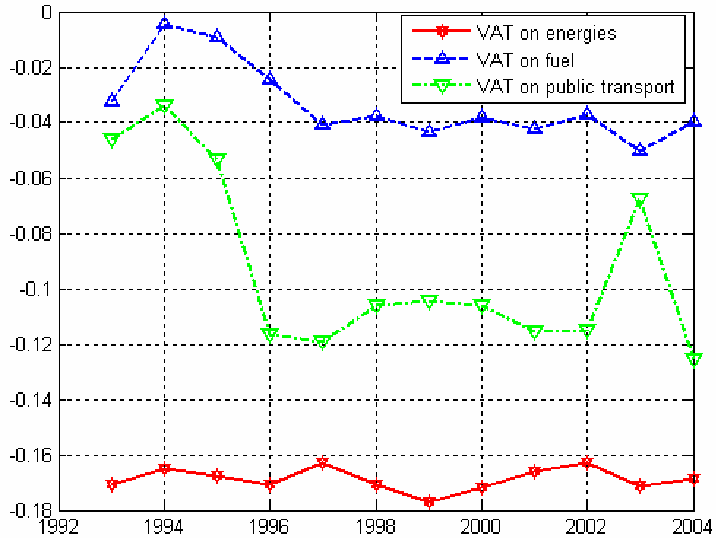
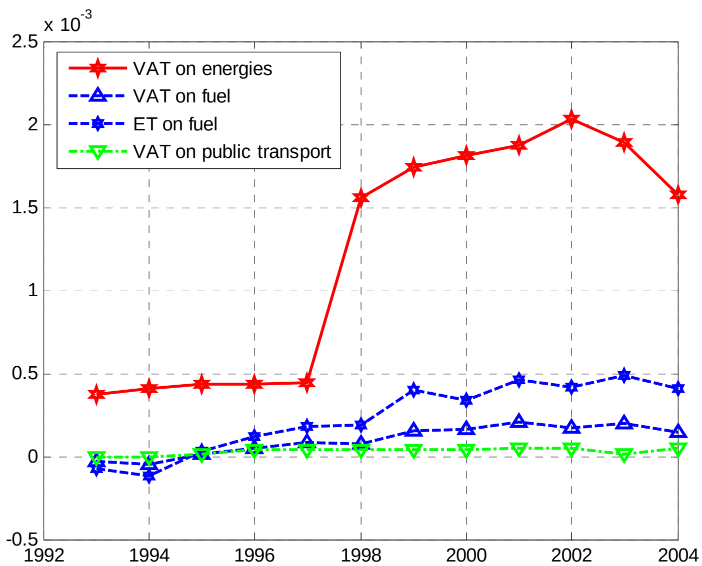


Figure IV-4: The Marginal Gini Indexes the environmental taxes.



This lesson teaches us that if inequality enters the welfare function of policymakers, revenue recycling options should be carefully investigated. Cuts in lower labour income bands can mitigate the regressive nature of energy taxes. Despite this normative reason, there may also be a political

– and economy issue. A careful design of taxed items and the revenue recycling options of an 'explicit' environmental tax reform may avoid having strongly socially adverse design of the (environmental) tax reform.

IV.1.3.2 Ex ante measurement of tax progressivity

Policy scenarios

In our *ex ante* tax progressivity measurement, we focus mostly on policy interventions related to the energy regulation. Our choice is supported by real political life: the revenue-neutral environmental tax reform is recently prepared by the Czech Government, therefore, we take its last proposal and use tax rates proposed there for the year 2011 (the third bi-annual step of tax rate increase since 2007) as a base of our simulations. As suggested in that ETR proposal (MoE, 2005), we also consider higher taxation of heat by shifting centrally-supplied heat from reduced 5% VAT rate to standard 19% rate. Hereinafter we refer this policy option as "*ETR*". We also simulate the effects of the environmental tax reform as suggested by MoE (2005) without increase in VAT on heat; this option is further marked as *"ETR_Heat5"*. Its parameters are the same with *"ETR"* policy option, however heat price is increased only by 24% in *"ETR_Heat5"*, instead of 36%.

Table IV-1: Description of the policy options simulated.

	Unit	Actual	ECmin	Heat_19	ETR	ETR_ insur	ETR_ labour	ETR 3,000	ETR 10,000	Fuel50
Excise taxes										
Coal	CZK/t	0	238	0	721	721	721	721	721	0
Gas	CZK/GJ	0	10	0	10	10	10	10	10	0
Electricity	CZK/MWh	0	30	0	431.5	431.5	431.5	431.5	431.5	0
Motor fuels	CZK/l	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	18.00
VAT										
Heat	%	5%	5%	19%	19%	19%	19%	19%	19%	5%
Energy prices, % change										
Coal	CZK/t	1,720	15%	0%	40%	40%	40%	40%	40%	0%
Gas	CZK/GJ	238	5%	0%	5%	5%	5%	5%	5%	0%
Heat	CZK/GJ	599	9%	13%	36%	36%	36%	36%	36%	0%
Electricity	CZK/kWh	2.6	1%	0%	18%	18%	18%	18%	18%	0%
Motor fuels	CZK/l	26.1	0%	0%	0%	0%	0%	0%	0%	25%
Revenue recycling option										
Insurance	%	12.5%	n.a.	n.a.	n.a.	10.45%				n.a.
Labour tax rate for the lowest bracket	%	12.0%	n.a.	n.a.	n.a.		8.82%	9.43%	10.85%	n.a.
Compensation										
Lump-sum transfer	CZK/hh bln.CZK	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,000 2.7	10,000 8.9	n.a.

In addition, we also simulate the impacts of other two possible real policy measures. As the first, we simulate the impacts due to the implementation of 96/2003/EC Directive on taxation on electricity and energy products. This legislative requirement would mean to introduce minimal rates of tax on electricity at 1 €/MWh, on coal at 7.9 €/t, and on gas at 0.33 €/GJ. We mark this option as "ECmin". Secondly, we simulate the impacts due to just increase in the VAT rate on heat from the actual lower rate of 5% to the standard rate of 19%. This option is marked by *"Heat_19"*.

Several mitigating and compensating measures could be introduced within the environmental tax reform in order to address possible adverse social effects. Ščasný and Brůha (2004) describe all possible such measures including a brief assessment of their effects on addressing the social impacts as well as possibly boost employment. In our simulation, we analyse two revenue recycling options of the environmental tax reform as designed in our "ETR" variant. These options include lowering direct labour taxation by decreasing the lowest marginal labour tax rate and lowering obligatory social and health insurance payments paid by employees. We mark these options as *"ETR_labour"*, and *"ETR_insur"* respectively. Labour tax or insurance rate cuts were calculated by our model and are reported in Table IV-1.

In addition to the revenue recycling policy variant, we experiment with two (arbitrary set out) options for social compensations. We introduce firstly lump-sum compensation to those households that would have expenditure shares on four energies and motor fuel after energy tax change higher than 20% of their total net expenditures. Then, we introduce (arbitrary too) lump-sum payment as high as 3,000 CZK (100€), or 10,000 CZK (333 €) respectively. We assume "revenue" neutrality of the option meaning that total additional tax revenues after energy tax change are fully used for these compensations and for labour taxation cuts. We assume lowering of the marginal labour tax rate set out for the first income bracket thus basing our two policy options on "ETR_labour" option. These options are then marked as *"ETR3,000"*, or *"ETR10,000"* respectively.

On the top, we analyse the effects due to 50% increase in excise tax on motor fuel; the option marked as *"Fuel50"*. Figure IV-1 reviews our policy scenarios including relevant tax rates, price changes and predicted parameters of labour taxation and social transfers.

Report design

Simulation results for a typical household group or income decile as well as for the entire Czech population are reported in the figures as follows. The reports of our simulations are reported in Appendix AIV-7, the reports for sensitivity analysis are enclosed in Tables in Appendix AIV-8.

An increase in energy expenditures (1st column), paid energy, fuel and transport taxes (2nd), direct and indirect labour taxation (3rd) while the negatives indicate lowered labour taxes and/or obligatory insurance contributions. Lump-sup social transfers are reported in the 4th column while the negatives indicate received transfer. Assuming revenue neutrality principle a sum of paid labour taxes and transfer should be equal to total additional public revenues gotten from increased energy taxation (before recycling).

Our estimate of additional expenditures needed to sustain household at the same utility level calculated on the base of cost-of-living indexes is in the 5th column. Change in household welfare is given as a difference between the change in net taxes (decreased labour tax or insurance payments and increased transfers) and estimated compensating expenditures; such welfare change is reported in the 6th column and its negatives indicate welfare loss.

The effects on public finances are reported in the next three columns; the additional public revenues from increased energy and fuel taxes (7th), the dead-weight-loss (8th), and total additional public revenues after revenue recycling and/or social transfer provided (last column).

Numbers reported just below the aggregates (1st row) then present the averages of changes in relevant variable for particular household appearing in relevant household group or income class.

All numbers are figured out in Czech crowns (2004-price level), while the aggregates are reported in billions of CZK after proper weighting. The aggregates refer to the overall impact on the entire Czech population.

We report the changes for three different household groups: firstly for income deciles, then for the household groups classified according to the heating source, and, lastly, for those groups as classified according to the social status of the head and the municipality size where the household live. Each household thus appears in each of three groups just once. Therefore, the aggregate changes in each considered variable *X*, e.g. in energy expenditures, are the same for each household group or class considered and is given as:

$$X = \sum_G \left(\frac{\sum_i PKOEF_{gi} \cdot X_{gi}}{\sum_i PKOEF_{gi}} \cdot Q_g \right) \qquad \text{(IV-7)}$$

where *I* denotes to a number of households in the group *g*, $PKOEF_{ig}$ is a weight of the household *i* located in the group *g* in the entire HBS sample, and *G* could equal to (1,…, 10) for income classes (deciles), to (1,…, 6) for the groups classified according to the heating source, or to (1,…, 13) respectively for our last group classification. Q_g is a number of households given group g in the entire population of the Czech Republic, while each household in the HBS sample is represented by the share $PKOEF/\Sigma_n PKOEF_n$ in the population. This allows us to compare distributional effects for various household groups more properly.

Report on relative change in welfare follows in Table IV-4. Change in expenditures is reported as a share of expenditures changed on net total household expenditures in Table IV-5. We calculate the Suits indexes before and after tax change; for better presentations our results we also draw a difference in two Suits indexes indicating an increase in tax regressivity, i.e. low-income groups pay more taxes, for its negative values (Tables IV-6). Results for the marginal Gini indexes conclude our distributional effect assessment by Tables IV-7 indicating growing income inequality by positive signs.

Our model allows us to simulate the impacts and parameters of policy (such decrease in labour tax rate or increase in deductibles) and other variables subject to keeping household welfare, household budget or public budgets unchanged. We follow hereinafter revenue neutrality criterion, i.e. we aim at keeping public budgets unchanged rather than household welfare. One can, however, easily use our model in order to assess distributional effects while following another normative criterion such as minimising DWL or impact on the households' budget.

Overall policy scenarios assessment

All policy option without revenue recycling results in lowering energy expenses, while revenue recycling and social lump-sum transfer provision increases these expenses. Following revenue neutrality principle, labour taxation can be lowered more than additional tax revenues from energy taxation due to additional VAT revenues from increased net incomes.

We identified 27% of households with higher expenditure share on energies and motor fuels than 20% of total household net expenditures in the HBS-2004 dataset. This share is reduced up to 19.5% after the "ETR" policy option introduced due to reduced energy consumption and expenditures (there are still almost 8% households with more than 25%-share, and 3% of households with the share higher than 30%). Authority would then need 2.7 billion CZK, or 8.9 billion CZK respectively to compensate such defined households by providing 3,000, or 10,000 CZK lump-sum social transfer.[9] Then, we get from our model that the lowest

[9] The authority could provide lump-sum transfer for such households as high as about 15,700 CZK if all additional tax revenues were used for social compensations under the ETR policy option. Although, total additional tax revenues from energy taxation are about 11.1 bln. CZK, the authority could provide about 14 bln. CZK of lump-sum transfers not increasing total tax burden. It is due to additional VAT revenues from expenses on goods

labour tax rate could be lowered – keeping revenue neutrality – from 12.0% to 9.43% (*ETR3,000*), or to 10.85% (*ETR10,000*), instead of 8.8% under *"ETR_labour"* option without providing such transfers. Social compensation reduces the share of such households (with higher than 20% share of energy and fuel expenses on net total expenditures) down to 18% (ETR3,000), or to 16% (ETR10,000).

Relative DWL — measured as 1 CZK of DWL per 1 CZK of additional revenues from energy tax — is the highest for the *"ECmin"* option (1.8). The ETR without higher taxation of heat generate lower inefficiency as high as 0.9, while the ETR with higher taxation on heat yield share of 0.7. Regarding the efficiency, fuel taxation is better-off than energy taxation; Fuel50 yield DWL of 0.6 per unit of additional tax revenues. Revenue recycling reduces disefficiency; DWL is about 0.4 per unit of additional tax revenues from higher energy taxation. As already argued, as we do not model effects on labour supply, DWL is underestimated and equal for each policy options including revenue recycling too. The lowest DWL produces *"Heat_19"* option; it is as high as 0.06 CZK per unit of additional tax revenues. One can get similar outcomes if welfare effects (CV) per tax revenues were compared. *"ECmin"* option yields the highest relative welfare loss (2.8 of CV per one unit of tax revenues), *"Heat_19"* yields the lowest one (1.06 of CV per unit of tax revenues).

Table IV-2: Comparison of policy options.

In bln. CZK	Impact on households						Public finances		
	energy expenses	paid eco taxes	paid labor taxes	transfer	CV (CLI)	Welfare	addit. public revenues	DWL	total revenues
ECmin	-0.13	1.8	0.0	0.0	5.1	-5.1	1.8	3.3	1.8
Heat_19	-1.35	3.4	0.0	0.0	3.8	-3.8	3.6	0.2	3.6
ETR_Heat5	-1.16	7.9	0.0	0.0	15.6	-15.6	8.1	7.5	8.1
ETR	-0.08	11.1	0.0	0.0	18.6	-18.6	11.1	7.5	11.1
ETR_insur	0.64	11.4	-13.9	0.0	18.7	-4.7	11.3	4.7	0.0
ETR_labour	0.65	11.4	-13.9	0.0	18.7	-4.7	11.3	4.7	0.0
ETR3,000	0.70	11.4	-11.2	-2.7	18.7	-4.7	11.3	4.7	0.0
ETR10,000	0.79	11.4	-4.9	-8.9	18.7	-4.7	11.3	4.7	0.0
Fuel50	4.34	6.2	0.0	0.0	8.9	-8.9	5.5	3.4	5.5

Despite of reduced energy expenses, all policy option would reduce energy consumption, except consumption for gas. Revenue recycling increases energy consumption, particularly due to income effect of motor fuels. Social transfer further increases energy consumption, particularly of coal. Fifty percent increase of excise tax on motor fuels (without revenue recycling) would reduce their consumption by about 14%.

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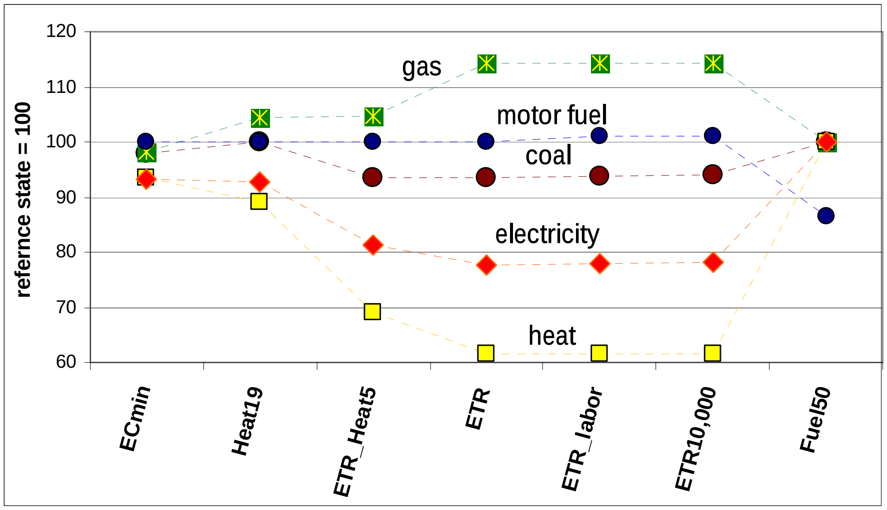
spent thanks to new social transfers. There would be still almost 15% of households after these lump-sum transfers provided with more than 20% expenditure share on energies and motor fuels.

Figure IV-5: Change in energy consumption for policy measures.



As already noted, our model allows simulating the impacts and parameters of policy subject to minimising household welfare, household budget or public budgets, and dead-weight-loss. Simulation results for the *"ETR"* policy option under different optimality criteria are shown in Table IV-3. Revenue recycling – keeping revenue neutrality, i.e. public revenues unchanged - would reduce DWL at least by about 40%[10] and welfare losses by 25% (in comparison with no recycling). The ETR yielding zero DWL would be only reached if labour taxation and public tax revenues were significantly reduced (bringing new incomes for the households). Households' budgets can be sustained unchanged only with welfare and dead-weight losses, but with additional public revenues. Households' welfare can be sustained unchanged only with state budget deficit and DWL.

Table IV-3: Result simulations for ***ETR*** under different optimality criteria.

	Household budget	Household welfare	State budget	DWL	Insurance rate	Labour tax
"ETR" policy option	-0.08	-18.6	11.1	7.5	12.50%	12.00%
Household budget = 0	0	-18.7	11.2	7.5	12.51%	12.02%
Household welfare = 0	17.8	0	-3.8	3.8	9.76%	7.75%
State budget = 0	13.3	-4.7	0	4.7	10.45%	8.82%
DWL = 0	35.8	18.9	-18.9	0	6.96%	3.45%

Implementation of the EU requirements

Higher heat taxation (*Heat_19*) would decrease energy expenditures (-1.35 bln. CZK) and simultaneously increase paid taxes (+3.39 bln. CZK). Dead-weight-loss per unit of tax revenues is the lowest among policy options. Although VAT tax on heat is progressive (increase of

[10] We highlight our comment on upper estimate of DWL for any policy option with revenue recycling.

Suits), overall energy and fuel taxation become slightly regressive (decrease in Suits). Overall taxation becomes regressive confirmed by both indexes. Change in welfare (-3.84 bln. CZK) is mostly affected the households of the first three deciles (welfare loss by 0.50% of total net expenditures), the household of pensioners or with one economically active person (*EA1* and *EA1+*) living in big cities (0.85, 0.62, and 0.49 respectively). In these households, energy expenditures are reduced as the most too. Higher heat taxation involves higher expenditures on heat and coal, however, decreases expenditures on electricity. Obviously, welfare of households that consume centrally-supplied heat (*HEATcookELE* and *HEATblocks*) is affected as the most *(by* 0.82%).

The implementation of EC Energy Taxation Directive decreases energy expenses by 0.13 bln. CZK. Energy expenditures after tax change are almost the same in average for each income class. Energy expenditures are reduced in the households of HEATcookELE, HEATblocks and GASheat, and slightly in the households living in municipalities with more than 2,000 inhabitants. These expenditures are increasing due to *"EC_min"* with large families living in bigger towns; they increased mostly in the households that use solid fuels for heating. Welfare loss declines with economic wealth, i.e. with income deciles and increases with the size of the municipality. The highest welfare loss appear in the households of pensioners, of the households that are connected on centrally-supplied heat (HEATcookELE, HEATblocks) and those ones that use solid fuels for heating (COALheat). The welfare impacts are in general higher in *"EC_min"* than under *"Heat_19"*, however less unequally distributed.

Environmental Tax Reform

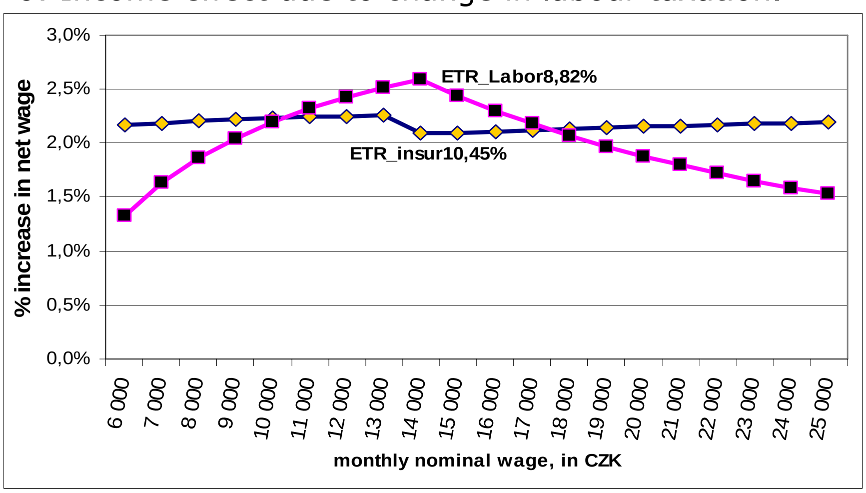
The environmental tax reform as described above decreases energy expenses by 0.08 bln. CZK (1.16 bln. CZK without heat taxation). The welfare impacts and changes in energy expenditures are similar to the *"EC_min"* option. Energy expenditures are reduced mostly in the households of HEATcookELE, slightly in HEATblocks and GASheat, on the other hand, the energy expenditures are increased in the households with electric and coal heaters. These expenses are reduced in the households living in bigger municipalities (and increased in villages). Welfare loss again declines with income deciles. Welfare of households living in bigger municipalities, of the pensioners, of the households that are connected on centrally-supplied heat (HEATcookELE, HEATblocks) and use solid fuels for heating (COALheat) is affected as the most. Welfare of pensioners living in big cities is reduced as the most among the analysed groups, by 3.02% of total expenditures. The impacts are similar for two ETR variants, whilst the impacts are higher for the option including also higher VAT taxation of heat. The implementation of the EC Directive is more regressive than *"Heat_19"* option. Confirmed by both indexes, *"ETR"* option is then more income and tax regressive than *"ETR_Heat5"*.

The ETR variants recycling the revenues via lowering obligatory social and health insurance payments paid by employees (*ETR_insurance*) and via lowering the lowest rate of direct labour taxation (*ETR_labour*) slightly increase energy expenditures if compared with original pre-tax level or with *"ETR"* option. *"ETR_insurance"* slightly more increases energy expenditures of first four deciles.

Revenue recycling also reduces welfare losses involved by the energy taxation introduced as in *"ETR"*. Welfare impact is even positive in the last three highest income deciles, in the households that use gas for heating (GASheat), and in the households with at least 2 economic active person (and having earnings from labour market). Negative welfare effects are smaller in villages. Welfare of households that are connected on centrally-supplied heat (HEATcookELE and HEATblocks) remains to be negatively affected after revenue recycling as the most among the groups (about -1.1% of net total expenditures).

After revenue recycling, welfare losses are lowered more particularly in the first four deciles under the *"ETR_insurance"* option. Lower regressivity of *"ETR_insurance"* option is also confirmed by the Suits and Gini indexes. Lesser regressivity of the ETR option recycling the revenues via insurance payments is due to taxation scheme being introduced in the Czech Republic. As shown in Figure IV-6, thanks to the interaction of direct labour taxation and social and health insurance scheme, *"ETR_insurance"* increases net incomes of employee with monthly nominal wage lower than about 10,000 CZK (and higher than 18,000 CZK too) more than *"ETR_labour"*.

Figure IV-6: Income effect due to change in labour taxation.



Provision of lump-sum transfers decreases welfare loss of the first five deciles on detriment of higher welfare losses of richer households (located in the five highest deciles). *"ETR10,000"* yields welfare losses distributed relatively evenly among deciles, while the lowest losses appear in the first (poorest) deciles. Welfare of deciles 4 and 5 – with the highest share of pensioners in the decile – is negatively affected as the most. Relatively higher welfare losses of pensioners confirmed by figure showing impacts for the households classified according to the social status and municipality size. The losses are increasing with the size of the municipality where the pensioners live; *"ETR3,000"* results in welfare losses of pensioners as high as -1.2, -1.7 and -2.4 (for small, medium, and big city). *"ETR10,000"* option however lowers pensioners' losses only if living in cities (above 20,000 inhabitants), while welfare of pensioners living in villages and small towns is even increased.

Larger families with more members (children) living in bigger municipalities presents the second sensitive group; welfare losses are in average -0.9% for *"ETR3,000"*, the option of *"ETR10,000"* even increases their losses at -1.0% of their total net expenditures. Moreover, welfare of households that are connected on heat remains to be reduced as the most among the groups classified according to the heating source. Similarly as for the larger families living in bigger cities, their welfare is in average even reduced if more lump-sum transfers were provided (thanks to smaller labour taxation cuts).

Lump-sum transfer provided with revenue recycling via lowering obligatory social and health insurance payments will lower welfare losses of poorer households even more. Welfare of the households of pensioners and larger families living in bigger cities remain, however, affected as the most.

Reduction of income and tax regressivity under the provision of lump-sum social transfers is also confirmed by both indexes we use.

Motor fuel taxation

We conclude that higher motor fuel taxation, as designed above, would yield almost two times more revenues, but with one order smaller DWL than the ECmin variant. It would also yield much more additional public revenues per unit of DWL if compared with the ETR variant.

Welfare effects due to *Fuel50* are relatively equally distributed among decile groups (between -0.7% to -1.0% of total expenditures). Welfare of the household of farmers and those living in villages (*EA1+small*, *EA2small* and *EA2+small*) is negatively affected as the most (up to -1.33%). It indicates higher propensity to car use in smaller cities. Excise tax on fuel is slightly regressive (Suits index falls by 0.002 at -0.0418), as VAT on public means of transport also becomes more regressive. Regressivity of the entire tax system is increasing too.

Table IV-4: Changes in **households' welfare** as the share of total net expenditures.

household group	ECmin	Heat19	ETR_Heat5	ETR	ETR_ insur	ETR_ labour	ETR3,000 (labour)	ETR10,000 (labour)	ETR3,000 (insur)	ETR10,000 (insur)	Fuel50
1	-0.70%	-0.51%	-2.14%	-2.55%	-1.60%	-1.90%	-1.38%	-0.15%	-1.13%	-0.04%	-0.72%
2	-0.65%	-0.49%	-1.99%	-2.38%	-1.31%	-1.48%	-1.09%	-0.19%	-0.95%	-0.12%	-0.82%
3	-0.71%	-0.55%	-2.12%	-2.56%	-1.60%	-1.64%	-1.25%	-0.33%	-1.21%	-0.31%	-0.76%
4	-0.63%	-0.48%	-1.97%	-2.35%	-1.44%	-1.55%	-1.27%	-0.61%	-1.18%	-0.57%	-0.78%
5	-0.61%	-0.48%	-1.78%	-2.17%	-0.98%	-0.93%	-0.87%	-0.70%	-0.90%	-0.72%	-0.90%
6	-0.48%	-0.34%	-1.54%	-1.81%	-0.39%	-0.26%	-0.33%	-0.49%	-0.43%	-0.53%	-0.98%
7	-0.49%	-0.32%	-1.50%	-1.75%	-0.16%	-0.03%	-0.15%	-0.43%	-0.26%	-0.48%	-1.04%
8	-0.45%	-0.34%	-1.35%	-1.62%	0.06%	0.21%	0.00%	-0.50%	-0.12%	-0.56%	-0.92%
9	-0.49%	-0.37%	-1.44%	-1.73%	0.06%	0.20%	-0.04%	-0.61%	-0.16%	-0.66%	-0.99%
10	-0.37%	-0.30%	-1.12%	-1.35%	0.45%	0.30%	0.05%	-0.54%	0.17%	-0.48%	-0.97%
ELECTRA	-0.12%	0%	-1.60%	-1.60%	-0.17%	-0.07%	0.06%	0.34%	-0.03%	0.31%	-1.23%
ELEcookGAS	-0.29%	0%	-1.28%	-1.28%	-0.09%	0.05%	0.26%	0.75%	0.15%	0.70%	-1.03%
HEATcookELE	-0.65%	-0.81%	-1.91%	-2.52%	-1.14%	-1.16%	-1.34%	-1.77%	-1.33%	-1.77%	-0.78%
HEATblocks	-0.69%	-0.82%	-1.87%	-2.54%	-1.09%	-1.13%	-1.17%	-1.25%	-1.13%	-1.24%	-0.80%
GASheat	-0.38%	0%	-1.05%	-1.05%	0.36%	0.38%	0.41%	0.47%	0.39%	0.46%	-0.91%
COALheat	-0.58%	0%	-2.34%	-2.34%	-0.85%	-0.80%	-0.64%	-0.24%	-0.67%	-0.26%	-1.31%
farmer_small	-0.38%	-0.02%	-1.61%	-1.63%	0.22%	0.09%	0.09%	0.07%	0.19%	0.12%	-1.15%
farmer_big	-0.40%	-0.15%	-1.40%	-1.52%	0.14%	-0.02%	-0.08%	-0.22%	0.05%	-0.16%	-1.25%
retired_small	-0.66%	-0.02%	-2.34%	-2.35%	-2.31%	-2.35%	-1.21%	1.46%	-1.18%	1.47%	-0.84%
retired_mid	-0.68%	-0.45%	-2.08%	-2.44%	-2.40%	-2.44%	-1.68%	0.11%	-1.64%	0.13%	-0.74%
retired_big	-0.85%	-0.85%	-2.33%	-3.02%	-2.97%	-3.02%	-2.40%	-0.94%	-2.36%	-0.93%	-0.51%
EA1_small	-0.39%	-0.04%	-1.51%	-1.55%	-0.43%	-0.09%	0.33%	1.32%	0.06%	1.20%	-0.90%
EA1_big	-0.64%	-0.62%	-1.76%	-2.26%	-0.60%	-0.53%	-0.51%	-0.45%	-0.56%	-0.48%	-0.57%
EA1+_small	-0.45%	-0.05%	-1.69%	-1.74%	-0.48%	-0.62%	-0.36%	0.25%	-0.25%	0.29%	-1.33%
EA1+_big	-0.55%	-0.49%	-1.62%	-2.02%	-0.74%	-0.90%	-0.93%	-1.00%	-0.80%	-0.94%	-0.83%
EA2_small	-0.42%	-0.05%	-1.47%	-1.51%	0.37%	0.55%	0.45%	0.20%	0.30%	0.14%	-1.13%
EA2_big	-0.51%	-0.41%	-1.48%	-1.81%	0.32%	0.43%	0.21%	-0.30%	0.12%	-0.34%	-1.05%
EA2+_small	-0.37%	-0.02%	-1.44%	-1.45%	0.35%	0.47%	0.31%	-0.05%	0.22%	-0.09%	-1.33%
EA2+_big	-0.43%	-0.36%	-1.29%	-1.58%	0.24%	0.28%	-0.01%	-0.69%	-0.04%	-0.71%	-0.96%

Table IV-5: Changes in **household expenditures** on energies and fuels as the share of total net expenditures.

household group	actual net expenditures	ECmin	Heat19	ETR_Heat5	ETR	ETR_ insur	ETR_ Labour	ETR3,000 (labour)	ETR10,000 (labour)	ETR3,000 (insur)	ETR10,000 (insur)	Fuel50
1	150 572	0.03%	-0.14%	0.02%	0.22%	0.28%	0.26%	0.30%	0.38%	0.31%	0.38%	0.34%
2	160 737	-0.06%	-0.18%	-0.26%	-0.16%	-0.10%	-0.11%	-0.08%	-0.02%	-0.07%	-0.02%	0.40%
3	168 910	0.01%	-0.15%	-0.12%	0.05%	0.11%	0.11%	0.13%	0.18%	0.13%	0.18%	0.35%
4	185 834	-0.03%	-0.19%	-0.15%	-0.03%	0.02%	0.01%	0.03%	0.07%	0.03%	0.07%	0.37%
5	208 036	-0.03%	-0.16%	-0.21%	-0.06%	0.00%	0.01%	0.02%	0.03%	0.01%	0.03%	0.44%
6	241 720	0.02%	-0.10%	0.04%	0.18%	0.26%	0.26%	0.27%	0.27%	0.26%	0.27%	0.48%
7	261 033	0%	-0.12%	-0.03%	0.05%	0.14%	0.15%	0.14%	0.14%	0.14%	0.14%	0.50%
8	284 742	-0.03%	-0.15%	-0.16%	-0.08%	0.00%	0.01%	0.00%	-0.01%	0.00%	-0.02%	0.46%
9	290 566	-0.02%	-0.15%	-0.18%	-0.11%	-0.03%	-0.02%	-0.03%	-0.05%	-0.03%	-0.05%	0.49%
10	361 757	-0.02%	-0.11%	-0.14%	-0.04%	0.04%	0.03%	0.02%	0.00%	0.03%	0.00%	0.49%
ELECTRA	222 025	0.06%	0%	0.76%	0.76%	0.86%	0.87%	0.90%	0.96%	0.89%	0.95%	0.58%
ELEcookGAS	198 443	-0.28%	0%	0.15%	0.15%	0.25%	0.27%	0.32%	0.44%	0.31%	0.43%	0.52%
HEATcookELE	210 202	-0.63%	-0.77%	-1.81%	-2.33%	-2.26%	-2.26%	-2.27%	-2.29%	-2.27%	-2.29%	0.38%
HEATblocks	230 536	0.14%	-0.15%	-0.28%	0.16%	0.23%	0.23%	0.23%	0.22%	0.23%	0.22%	0.40%
GASheat	242 142	-0.15%	0%	-0.16%	-0.16%	-0.09%	-0.09%	-0.08%	-0.07%	-0.08%	-0.07%	0.45%
COALheat	235 941	0.59%	0%	2.06%	2.06%	2.17%	2.17%	2.19%	2.23%	2.19%	2.23%	0.63%
farmer_small	243 001	0.16%	0%	0.92%	0.96%	1.07%	1.07%	1.07%	1.08%	1.08%	1.08%	0.61%
farmer_big	280 983	-0.05%	-0.13%	0.13%	0.13%	0.24%	0.23%	0.23%	0.23%	0.24%	0.24%	1.17%
retired_small	146 199	0.08%	-0.03%	0.75%	0.73%	0.73%	0.73%	0.81%	0.99%	0.81%	0.99%	0.47%
retired_mid	131 725	-0.06%	-0.11%	-0.09%	0.13%	0.13%	0.13%	0.18%	0.29%	0.18%	0.29%	0.26%
retired_big	133 461	0.01%	-0.20%	-0.49%	-0.16%	-0.16%	-0.16%	-0.13%	-0.06%	-0.13%	-0.06%	0.27%
EA1_small	171 598	0.01%	-0.02%	0.31%	0.33%	0.39%	0.43%	0.48%	0.58%	0.45%	0.57%	0.40%
EA1_big	161 147	-0.07%	-0.21%	-0.52%	-0.37%	-0.30%	-0.29%	-0.28%	-0.27%	-0.29%	-0.27%	0.29%
EA1+_small	219 139	0.11%	-0.03%	0.72%	0.75%	0.84%	0.83%	0.86%	0.92%	0.86%	0.92%	0.58%
EA1+_big	241 308	-0.06%	-0.20%	-0.36%	-0.26%	-0.19%	-0.19%	-0.19%	-0.19%	-0.19%	-0.18%	0.32%
EA2_small	274 278	0.06%	-0.01%	0.43%	0.45%	0.55%	0.56%	0.56%	0.55%	0.55%	0.54%	0.45%
EA2_big	275 861	0%	-0.12%	-0.17%	-0.03%	0.07%	0.08%	0.07%	0.06%	0.07%	0.06%	0.54%
EA2+_small	316 205	0.12%	-0.02%	0.67%	0.66%	0.79%	0.80%	0.79%	0.78%	0.79%	0.78%	0.62%
EA2+_big	338 036	-0.05%	-0.15%	-0.24%	-0.16%	-0.07%	-0.07%	-0.08%	-0.11%	-0.08%	-0.11%	0.51%

Table IV-6a: The Suits indexes.

	Actual	ECmin	Heat19	ETR_Heat5	ETR	ETR_ insurance	ETR_ labour	ETR 3,000	ETR 10,000	Fuel50
SUITS										
direct labour taxation	0.177	0.179	0.178	0.179	0.179	0.180	0.208	0.200	0.184	0.176
Insurance	0.049	0.051	0.050	0.051	0.051	0.053	0.054	0.052	0.046	0.047
Excise tax: fuel	-0.040	-0.038	-0.040	-0.037	-0.037	-0.037	-0.036	-0.036	-0.037	-0.042
Excise tax: energy		-0.170			-0.183	-0.182	-0.181	-0.180	0.182	
VAT on fuel	-0.040	-0.038	-0.040	-0.037	-0.037	-0.037	-0.036	-0.036	-0.037	-0.042
VAT public transport	-0.122	-0.119	-0.121	-0.119	-0.119	-0.116	-0.116	-0.119	-0.128	-0.123
ECO TAXES	-0.083	-0.086	-0.088	-0.100	-0.103	-0.102	-0.101	-0.101	-0.101	-0.077
VAT on energy	-0.167	-0.166	-0.162	-0.167	-0.163	-0.163	-0.162	-0.162	-0.160	-0.165
VAT on rest	-0.028	-0.026	-0.027	-0.028	-0.028	-0.027	-0.027	-0.029	-0.034	-0.030
LABOR taxation	0.100	0.101	0.101	0.101	0.101	0.108	0.108	0.106	0.099	0.098
TAX Total	0.043	0.044	0.042	0.039	0.038	0.040	0.040	0.038	0.034	0.040

Table IV-6b: The Marginal Gini indexes.

	Actual	ECmin	Heat19	ETR_Heat5	ETR	ETR_ insurance	ETR_ labour	ETR 3,000	ETR 10,000	Fuel50
MARGINAL GINI										
DPFO	-0.052	0	0.0001	0.1973	0.1973	0.1986	0.2011	0.1999	0.1969	0.0002
Insurance	-0.045	0	0.0002	0.2037	0.2037	0.2075	0.2054	0.2048	0.2032	0.0006
Excise tax: fuel	-0.032	0	0	0.2169	0.2169	0.2191	0.2192	0.2182	0.2157	0.0001
Excise tax: energy		0.0002	0	0.2180	0.2180	0.2202	0.2203	0.2193	0.2167	0
VAT on fuel	-0.032	0	0	0.2170	0.2170	0.2191	0.2192	0.2182	0.2157	0
VAT public transport	-0.032	0	0	0.2170	0.2170	0.2192	0.2193	0.2183	0.2158	0
ECO TAXES	-0.031	0.0002	0.0004	0.2196	0.2200	0.2220	0.2222	0.2211	0.2186	0.0001
VAT on energy	-0.031	0	0.0003	0.2185	0.2189	0.2210	0.2211	0.2201	0.2175	0
VAT on rest	-0.033	0	0.0002	0.2161	0.2161	0.2181	0.2182	0.2175	0.2158	0.0006
LABOR taxation	-0.070	0	0.0003	0.1792	0.1792	0.1826	0.1830	0.1820	0.1799	0.0009
TAX Total	-0.078	0.0002	0.0010	0.1724	0.1727	0.1763	0.1767	0.1762	0.1754	0.0018

Table IV-7a: Change in the Suits Indexes after tax change in comparison with initial value of the Suits Index before tax-change, in 10^{-3}.

	Actual	ECmin	Heat19	Heat19 (average)	ETR_Heat5	ETR	ETR_ insurance	ETR_ labour	ETR 3,000	ETR 10,000	Fuel50	Fuel50 (average)
SUITS												
direct labour taxation	n.a.	1.6	0.9	1.6	1.6	1.6	2.5	30.1	22.8	6.3	**-1.3**	1.6
Insurance	n.a.	1.9	1.0	1.8	1.9	1.9	3.9	5.0	2.9	-2.4	**-1.5**	1.9
Excise tax: fuel	n.a.	2.1			2.4	2.4	3.0	4.0	3.6	2.6	**-2.3**	2.1
VAT on fuel	n.a.	2.1	0.0	1.9	2.1	2.1	2.7	3.7	3.3	2.3	**-2.3**	2.1
VAT public transport	n.a.	2.2	0.1	2.1	2.2	2.2	6.0	5.7	2.2	-6.1	**-1.1**	2.5
ECO TAXES	n.a.	**-2.5**	**-4.6**	**-3.1**	**-16.9**	**-19.7**	**-19.1**	**-18.3**	**-18.1**	**-17.4**	6.0	8.9
VAT on energy	n.a.	1.4	5.0	5.9	-0.4	4.1	4.3	4.6	5.3	7.2	2.5	2.3
VAT on rest	n.a.	2.1	1.0	1.9	0.3	0.5	1.1	0.9	**-1.0**	**-5.9**	**-1.5**	2.1
LABOR taxation	n.a.	1.8	0.9	1.7	1.8	1.8	8.6	8.5	5.9	-0.8	**-1.4**	1.8
TAX Total	n.a.	0.9	**-0.6**	0.3	**-3.7**	**-4.9**	**-3.3**	**-3.4**	**-4.9**	**-9.1**	**-2.7**	0.8

Note: Suits index is not defined for initial level of excise tax on energies as there is no such tax levied on households.
The negatives indicate *increase in tax regressivity*, i.e. the poorer pay more taxes (such cases are shaded).

Table IV-7a: Diffeences in the Marginal Gini indexes if compared the index after tax change and before tax change.

	Actual	ECmin	Heat19	Heat19 (average)	ETR_Heat5	ETR	ETR_ insurance	ETR_ labour	ETR 3,000	ETR 10,000	Fuel50	Fuel50 (average)
MARGINAL GINI												
DPFO	-0.052	0.0	0.6	-0.5	0.0	0.0	12.9	38.3	25.9	-3.7	2.4	0.0
Insurance	-0.045	0.0	1.6	-0.5	0.0	0.0	37.3	17.1	10.7	-5.1	5.7	0.0
Excise tax: fuel	-0.032	0.0	0.3	-0.5	0.0	0.0	21.1	22.2	12.3	-12.9	0.7	-0.1
Excise tax: energy		2.4			10.6	10.5	31.8	33.1	22.9	-2.8		
VAT on fuel	-0.032	0.0	0.0	-0.5	0.0	0.0	21.2	22.5	12.5	-12.9	0.0	0.0
VAT public transport	-0.032	0.0	-0.1	-0.5	0.0	0.0	21.3	22.7	12.6	-12.8	-0.2	0.0
ECO TAXES	-0.031	2.5	4.0	2.9	11.8	15.0	35.9	36.9	26.8	1.4	1.1	-0.1
VAT on energy	-0.031	0.0	3.5	2.8	0.7	3.9	25.1	26.5	16.3	-9.4	-0.2	0.0
VAT on rest	-0.033	0.0	1.6	-0.4	2.1	1.8	21.8	23.4	16.5	-0.7	5.7	0.0
LABOR taxation	-0.070	0.0	2.5	-0.4	0.0	0.0	34.1	38.0	28.6	7.6	9.5	0.0
TAX Total	-0.078	2.4	9.5	2.8	13.3	16.1	52.1	56.5	51.6	42.9	18.2	-4.1

Note: The positives indicate that income inequality is increased after tax change.

Sensitivity analysis

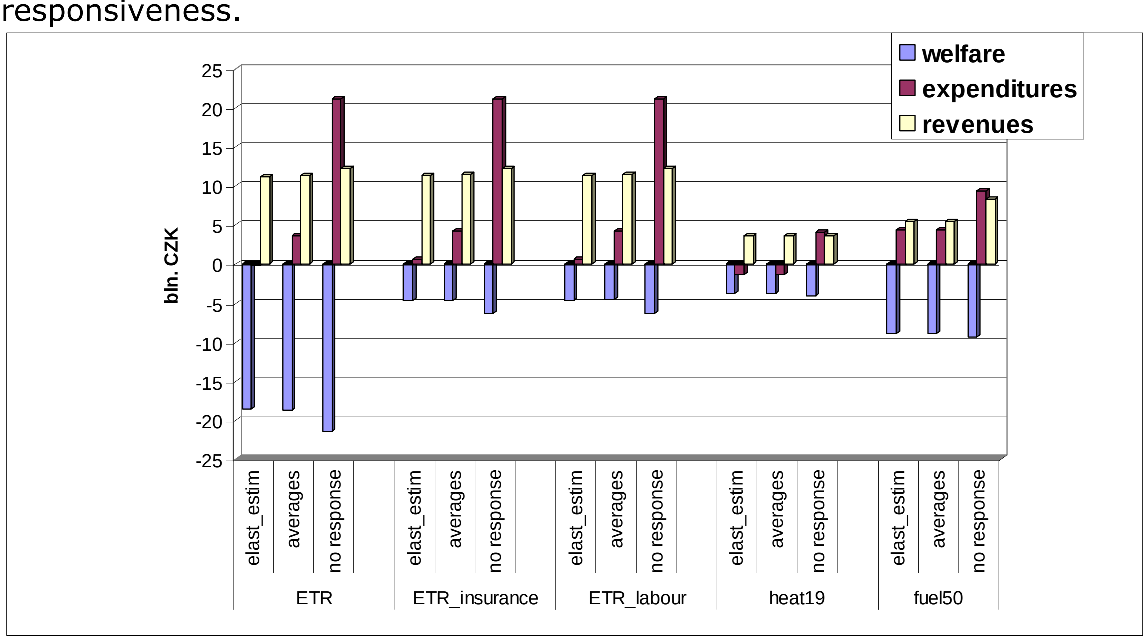
We perform a sensitivity analysis with respect to numerical values of elasticities, i.e. different assumptions on demand responsiveness on price and income changes.

Firstly, we examine how would the effects due to a policy intervention differ, if we assumed average responsiveness meaning that we apply for a weighted average of price and income elasticities for those households who consumed relevant good. Average elasticities for energy goods are calculated from the elasticities estimated for the household groups classified according to the heating source and weighted by a number of households in relevant group (see Section III.5).

Secondly, we examine how would the effects differ if we assumed fully unresponsive demands, meaning that no elasticity would be used in the distributional analysis.

We examine how the effects vary for several policy options: *"Heat_19"*, *"ETR"*, *"ETR_labour"*, *"ETR_insur"* and *"Fuel50"*. We thus get three reports (with our elasticity estimations, with their averages, and with no elasticities used) that can be easily compared.

Figure IV-7: Sensitivity analysis on assumption of demand responsiveness.



There is a clear conclusion: if no respond of demand on price and income changes was assumed (and no elasticities were used), the welfare impacts, energy expenditures and predicted additional public revenues from increased energy tax would be the highest. This is due to fully unresponsive energy demand on price effects. If one used a change in all analysed variables would be more close to the changes that considered the elasticities estimated properly for each relevant household group.

The impacts on public revenues are the lowest if the elasticity as estimated in Section III were used. The reason lays in an interaction of tax system when a revenue loss from one tax item can be balanced by an increase in revenues from the other tax item. Increased excise tax on energies could yield additional tax revenues, but it can also result in certain increase in energy expenditures. Considering the household budget constraints, increased energy tax would also result in lower consumption of the other goods. As these goods are taxed by value added tax, public finances would thus lose some revenues from VAT. This is also the reason why higher energy taxation due to VAT increase, e.g. on heat, would not yield different numbers for changes in additional public revenues under different assumption on demand responsiveness and under different changes in household energy consumption.

Different assumption on demand responsiveness, yielding different changes in energy demand and possibly in public revenues too, affect the parameters of policy measure, particularly the environmental tax reform. If demands are fully unresponsive (no elasticties used), much more revenues "can" be recycled through lowering the other (labour) taxes. For example, for the *"ETR"* option, while the lowest labour tax rate could be lowered from the actual 12% down to 8.82% if our elasticity estimations were used, the rate of labour tax could be cut down to 8.77% if the average elasticities were applied, or even to 8.5% if no demand response was assumed. We get similar results for the revenue recycling option of the ETR based on lowering social and health insurance rates: while the improperly considered demand responses would allow the authority to lower the rates from the actual 12.5% down to 10.27% (no response), or 10.42% (the averages), it would be reasonable to lower the rate only to 10.45%. The error of course depends on the scope of the reform considered. The small difference in prediction given by elasticity estimations and the averages is also because we apply averages from our estimates and only for those households that consumed relevant non-durable good; zero elasticity was applied for the rest of households in both cases.

We conclude that the average of demand responses will be conveniently used if no drastic tax reform is introduced. The state authority, however, should care about the predictions if an intervention brings bigger changes. On the other hand, if no demand responses were considered, a prediction could be heavily biased particularly if only the additional public revenues from increased taxes would be concerned by the authority.

The distributional concerns, however, remain for the sensitivity analysis. Even if the predicted aggregates would not differ so much under different assumption on demand responsiveness, the changes in household welfare and expenditures may significantly vary among the household groups; this is confirmed by our simulation results done under sensitivity analysis as shown in Tables AIV-8 in the Appendix.

Let's have a closer look at "*ETR*" policy variant. The welfare effects are about 20% higher if no demand respond was assumed. Differences in energy expenses are however even more significant; these expense would be changed by some hundreds (between -300 to +400 CZK) applying elasticity estimations, by 700 to 1,300 CZK if the averages used, or by thousands (if no response assumed). Welfare of the households of pensioners living in big municipalities is reduced by 3.6% of their total expenditures (no response), or 3.0% (with responsive demands). Welfare is reduced by 3.2% (no response), or by 2.5% (with responses) in the households that use centrally supplied heat. These differences are even higher for the energy expenditure: the expenses would be increased by 3.5% in the households of pensioners living in big cities if no response was considered, while the expenses would even fall down by 0.16%; similarly the energy expenses would rise by about 3% in the households that are connected on heat (HEATblocks, HEATcookELE), if no response was considered. These expenses would be however almost the same (+0.16% in HEATblocks) or even would fall down (-2.3% in HEATcookELE) if elasticities were used. One may draw many of such conclusions looking at the reports or applying the method here developed.

The reports on changes in household welfare and its energy expenditures follow in Table IV-8 and IV-9. One can compare the effects for income deciles, and two groups analysed. The Suits indexes and the marginal Gini indexes for some of variants are reported above in tables IV-6 and IV-7.

Table IV-8: Changes in households' welfare as the share of total net expenditures: sensitivity analysis for different demand responses.

household group	Heat_19			ETR			ETR_insurance			ETR_labour			Fuel50		
	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp
1	-0.51%	-0.51%	-0.53%	-2.55%	-2.57%	-2.93%	-1.60%	-1.78%	-2.09%	-1.90%	-2.03%	-2.35%	-0.72%	-0.73%	-0.77%
2	-0.49%	-0.49%	-0.52%	-2.38%	-2.40%	-2.76%	-1.31%	-1.52%	-1.81%	-1.48%	-1.66%	-1.97%	-0.82%	-0.82%	-0.87%
3	-0.55%	-0.55%	-0.58%	-2.56%	-2.57%	-2.96%	-1.60%	-1.78%	-2.11%	-1.64%	-1.82%	-2.15%	-0.76%	-0.76%	-0.81%
4	-0.48%	-0.48%	-0.51%	-2.35%	-2.37%	-2.72%	-1.44%	-1.62%	-1.91%	-1.55%	-1.71%	-2.01%	-0.78%	-0.79%	-0.83%
5	-0.48%	-0.48%	-0.51%	-2.17%	-2.18%	-2.52%	-0.98%	-1.20%	-1.47%	-0.93%	-1.17%	-1.43%	-0.90%	-0.90%	-0.96%
6	-0.34%	-0.34%	-0.36%	-1.81%	-1.82%	-2.06%	-0.39%	-0.65%	-0.81%	-0.26%	-0.55%	-0.70%	-0.98%	-0.98%	-1.04%
7	-0.32%	-0.32%	-0.34%	-1.75%	-1.77%	-2.00%	-0.16%	-0.46%	-0.59%	-0.03%	-0.35%	-0.47%	-1.04%	-1.04%	-1.11%
8	-0.34%	-0.34%	-0.36%	-1.62%	-1.63%	-1.87%	0.06%	-0.24%	-0.38%	0.21%	-0.12%	-0.25%	-0.92%	-0.92%	-0.98%
9	-0.37%	-0.37%	-0.39%	-1.73%	-1.74%	-2.00%	0.06%	-0.27%	-0.41%	0.20%	-0.15%	-0.29%	-0.99%	-0.99%	-1.05%
10	-0.30%	-0.30%	-0.31%	-1.35%	-1.36%	-1.57%	0.45%	0.12%	0.02%	0.30%	-0.01%	-0.11%	-0.97%	-0.97%	-1.03%
ELECTRA	0%	0%	0%	-1.60%	-1.62%	-1.67%	-0.17%	-0.45%	-0.41%	-0.07%	-0.37%	-0.31%	-1.23%	-1.23%	-1.31%
ELEcookGAS	0%	0%	0%	-1.28%	-1.35%	-1.37%	-0.09%	-0.37%	-0.32%	0.05%	-0.26%	-0.20%	-1.03%	-1.02%	-1.09%
HEATcookELE	-0.81%	-0.82%	-0.87%	-2.52%	-2.53%	-3.19%	-1.14%	-1.40%	-1.97%	-1.16%	-1.41%	-1.98%	-0.78%	-0.78%	-0.83%
HEATblocks	-0.82%	-0.82%	-0.86%	-2.54%	-2.51%	-3.06%	-1.09%	-1.32%	-1.78%	-1.13%	-1.36%	-1.82%	-0.80%	-0.80%	-0.85%
GASheat	0%	0%	0%	-1.05%	-1.10%	-1.11%	0.36%	0.07%	0.15%	0.38%	0.08%	0.16%	-0.91%	-0.91%	-0.97%
COALheat	0%	0%	0%	-2.34%	-2.35%	-2.36%	-0.85%	-1.13%	-1.04%	-0.80%	-1.09%	-1.00%	-1.31%	-1.31%	-1.39%
farmer_small	-0.02%	-0.02%	-0.02%	-1.63%	-1.65%	-1.68%	0.22%	-0.14%	-0.05%	0.09%	-0.24%	-0.16%	-1.15%	-1.15%	-1.22%
farmer_big	-0.15%	-0.15%	-0.16%	-1.52%	-1.54%	-1.67%	0.14%	-0.18%	-0.20%	-0.02%	-0.31%	-0.34%	-1.25%	-1.19%	-1.26%
retired_small	-0.02%	-0.02%	-0.02%	-2.35%	-2.41%	-2.45%	-2.31%	-2.38%	-2.41%	-2.35%	-2.41%	-2.45%	-0.84%	-0.83%	-0.88%
retired_mid	-0.45%	-0.45%	-0.48%	-2.44%	-2.46%	-2.79%	-2.40%	-2.43%	-2.75%	-2.44%	-2.46%	-2.79%	-0.74%	-0.75%	-0.79%
retired_big	-0.85%	-0.85%	-0.90%	-3.02%	-3.02%	-3.61%	-2.97%	-2.98%	-3.57%	-3.02%	-3.02%	-3.61%	-0.51%	-0.51%	-0.54%
EA1_small	-0.04%	-0.04%	-0.05%	-1.55%	-1.59%	-1.63%	-0.43%	-0.67%	-0.65%	-0.09%	-0.39%	-0.34%	-0.90%	-0.91%	-0.96%
EA1_big	-0.62%	-0.62%	-0.66%	-2.26%	-2.26%	-2.71%	-0.60%	-0.90%	-1.24%	-0.53%	-0.85%	-1.17%	-0.57%	-0.57%	-0.61%
EA1+_small	-0.05%	-0.05%	-0.06%	-1.74%	-1.76%	-1.82%	-0.48%	-0.73%	-0.71%	-0.62%	-0.85%	-0.83%	-1.33%	-1.33%	-1.41%
EA1+_big	-0.49%	-0.49%	-0.52%	-2.02%	-2.02%	-2.38%	-0.74%	-0.97%	-1.24%	-0.90%	-1.10%	-1.39%	-0.83%	-0.84%	-0.89%
EA2_small	-0.05%	-0.05%	-0.05%	-1.51%	-1.54%	-1.59%	0.37%	0.00%	0.08%	0.55%	0.15%	0.23%	-1.13%	-1.13%	-1.20%
EA2_big	-0.41%	-0.41%	-0.43%	-1.81%	-1.81%	-2.10%	0.32%	-0.06%	-0.22%	0.43%	0.03%	-0.12%	-1.05%	-1.05%	-1.11%
EA2+_small	-0.02%	-0.02%	-0.02%	-1.45%	-1.48%	-1.50%	0.35%	0.01%	0.09%	0.47%	0.10%	0.20%	-1.33%	-1.32%	-1.41%
EA2+_big	-0.36%	-0.36%	-0.38%	-1.58%	-1.58%	-1.84%	0.24%	-0.09%	-0.24%	0.28%	-0.06%	-0.20%	-0.96%	-0.96%	-1.01%

Table IV-9: Changes in household expenditures on energies and fuels as the share of total net expenditures: sensitivity analysis for different demand responses.

household group	Heat_19			ETR			ETR_insurance			ETR_labour			Fule50		
	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp	elasticity	average	no resp
1	-0.14%	-0.15%	0.53%	0.22%	0.69%	2.87%	0.28%	0.75%	2.87%	0.26%	0.72%	2.87%	0.34%	0.36%	0.76%
2	-0.18%	-0.18%	0.52%	-0.16%	0.42%	2.71%	-0.10%	0.48%	2.71%	-0.11%	0.46%	2.71%	0.40%	0.41%	0.86%
3	-0.15%	-0.16%	0.57%	0.05%	0.50%	2.90%	0.11%	0.57%	2.90%	0.11%	0.54%	2.90%	0.35%	0.38%	0.80%
4	-0.19%	-0.19%	0.50%	-0.03%	0.38%	2.67%	0.02%	0.44%	2.67%	0.01%	0.41%	2.67%	0.37%	0.39%	0.83%
5	-0.16%	-0.17%	0.50%	-0.06%	0.32%	2.47%	0.00%	0.38%	2.47%	0.01%	0.37%	2.47%	0.44%	0.44%	0.95%
6	-0.10%	-0.11%	0.36%	0.18%	0.54%	2.03%	0.26%	0.61%	2.03%	0.26%	0.60%	2.03%	0.48%	0.48%	1.03%
7	-0.12%	-0.13%	0.34%	0.05%	0.47%	1.97%	0.14%	0.54%	1.97%	0.15%	0.54%	1.97%	0.50%	0.51%	1.10%
8	-0.15%	-0.16%	0.36%	-0.08%	0.23%	1.85%	0.00%	0.29%	1.85%	0.01%	0.29%	1.85%	0.46%	0.46%	0.97%
9	-0.15%	-0.15%	0.38%	-0.11%	0.23%	1.97%	-0.03%	0.29%	1.97%	-0.02%	0.30%	1.97%	0.49%	0.49%	1.04%
10	-0.11%	-0.11%	0.31%	-0.04%	0.19%	1.55%	0.04%	0.24%	1.55%	0.03%	0.24%	1.55%	0.49%	0.48%	1.02%
ELECTRA	0%	0%	0%	0.76%	1.08%	1.65%	0.86%	1.17%	1.65%	0.87%	1.16%	1.65%	0.58%	0.60%	1.29%
ELEcookGAS	0%	0%	0%	0.15%	1.30%	1.36%	0.25%	1.36%	1.36%	0.27%	1.35%	1.36%	0.52%	0.50%	1.08%
HEATcookELE	-0.77%	-0.67%	0.86%	-2.33%	-2.38%	3.13%	-2.26%	-2.32%	3.13%	-2.26%	-2.33%	3.13%	0.38%	0.39%	0.82%
HEATblocks	-0.15%	-0.20%	0.86%	0.16%	-0.42%	3.01%	0.23%	-0.36%	3.01%	0.23%	-0.37%	3.01%	0.40%	0.40%	0.84%
GASheat	0%	0%	0%	-0.16%	1.38%	1.10%	-0.09%	1.43%	1.10%	-0.09%	1.43%	1.10%	0.45%	0.45%	0.96%
COALheat	0%	0%	0%	2.06%	2.22%	2.32%	2.17%	2.31%	2.32%	2.17%	2.30%	2.32%	0.63%	0.64%	1.38%
farmer_small	0%	0%	0.02%	0.96%	1.58%	1.66%	1.07%	1.66%	1.66%	1.07%	1.66%	1.66%	0.61%	0.56%	1.21%
farmer_big	-0.13%	-0.13%	0.16%	0.13%	0.78%	1.65%	0.24%	0.87%	1.65%	0.23%	0.86%	1.65%	1.17%	0.58%	1.25%
retired_small	-0.03%	-0.03%	0.02%	0.73%	2.38%	2.41%	0.73%	2.45%	2.41%	0.73%	2.38%	2.41%	0.47%	0.40%	0.87%
retired_mid	-0.11%	-0.12%	0.47%	0.13%	0.92%	2.74%	0.13%	0.97%	2.74%	0.13%	0.92%	2.74%	0.26%	0.36%	0.79%
retired_big	-0.20%	-0.22%	0.89%	-0.16%	-0.09%	3.52%	-0.16%	-0.04%	3.52%	-0.16%	-0.09%	3.52%	0.27%	0.25%	0.54%
EA1_small	-0.02%	-0.02%	0.05%	0.33%	1.45%	1.61%	0.39%	1.50%	1.61%	0.43%	1.52%	1.61%	0.40%	0.45%	0.95%
EA1_big	-0.21%	-0.21%	0.65%	-0.37%	-0.22%	2.65%	-0.30%	-0.16%	2.65%	-0.29%	-0.16%	2.65%	0.29%	0.29%	0.60%
EA1+_small	-0.03%	-0.03%	0.06%	0.75%	1.55%	1.80%	0.84%	1.63%	1.80%	0.83%	1.62%	1.80%	0.58%	0.64%	1.40%
EA1+_big	-0.20%	-0.20%	0.52%	-0.26%	-0.03%	2.34%	-0.19%	0.02%	2.34%	-0.19%	0.02%	2.34%	0.32%	0.42%	0.88%
EA2_small	-0.01%	-0.01%	0.05%	0.45%	1.45%	1.57%	0.55%	1.53%	1.57%	0.56%	1.53%	1.57%	0.45%	0.55%	1.19%
EA2_big	-0.12%	-0.13%	0.43%	-0.03%	0.26%	2.07%	0.07%	0.33%	2.07%	0.08%	0.33%	2.07%	0.54%	0.51%	1.10%
EA2+_small	-0.02%	-0.02%	0.02%	0.66%	1.37%	1.49%	0.79%	1.45%	1.49%	0.80%	1.46%	1.49%	0.62%	0.65%	1.39%
EA2+_big	-0.15%	-0.15%	0.38%	-0.16%	0.09%	1.82%	-0.07%	0.15%	1.82%	-0.07%	0.15%	1.82%	0.51%	0.47%	1.01%

IV.2 Welfare measurement of changes in environmental quality

IV.2.1 Introduction to measurement

As has already been discussed in Section II.1.3, one may follow several competing notions of equity fairness while analysing disparities in distribution of environmental quality.

If an equality of physical effects (of exposure or risks) is normatively required, these effects should be evenly distributed regardless of their valuation or preference for differences among households.

However, if the preference-based notion of equity is followed and an equal distribution is required, the welfare effects associated with a change in environmental quality will have to be evenly distributed rather than the physical effects that these welfare effects involved.[11] As subjective perception of physical changes varies across households, relevant welfare changes due to the same physical effects received would vary across households too, i.e. the wealthier households tend to enjoy, thus value, certain environmental quality relatively more than the poorer ones.

Following the preference-based notion of equity, the 'fair' distribution outcome given under the physical approach of exposure or risk could thus be considered 'unfair'. Let us make one example here: Let us assume that a certain intervention reduces the ambient concentration of air pollution (and relevant adverse health effects too) equally for each household. It also involves financial effects that are distributed perfectly evenly across the household income groups. Such an intervention seems to be perfectly even and keep the initial welfare distribution unchanged. This statement, however, would only hold if the exposure or risks notion of equality was followed. An intervention yielding the same physical effects for each household, however, could increase the welfare of the richer more than that of the poorer. The 'fair' intervention with even distribution can therefore be regressive in this view, providing 'unfair' distribution and consequently increasing the inequality.

[11] One caveat may be stressed: if the welfare effects of environmental quality are uniformly distributed across different socio-economic groups, a policy may even tend to relatively reduce the initial wealth inequality. It may be because these welfare effects present a proportionally larger share of the total welfare of the low-income households than is the case with the richer ones.

This has clear implications for any environmental and social policy if distributional aspects are concerned: the state authority should choose the "right" normative notion of equity he/she preferably likes to follow.

We support here the preference-based notion that requires an appropriate benefit valuation based on individuals' preference for a relevant physical change in environmental quality, such as the provision of an environmental good, exposure or perceived associated risks.

Welfare measurement of changes in environmental quality is then straightforward as described in detail in Section II.2.4. Following the basics of neoclassical economics, an appropriate welfare measurement requires the application of one of the valuation methods. If non-market goods and services are concerned, one will need to apply one of the non-market valuation methods.[12] Then, welfare measures such as compensating or equivalent surplus can be derived. Thanks to using the same units, such valuation outcomes can be summed up with welfare changes due to the involved financial effects.

Empirical literature, however, suggests that such welfare measures may vary across households. Ideally, one would need a specific welfare change for each affected household. In practice, one may rely on estimates for income elasticity of demand for a concerned environmental quality. These estimates can be particularly useful where the disparities in distribution of environmental quality for different income household groups are concerned.

If one should conduct a comprehensive assessment of welfare disparities, outcomes given by preference analysis need to be directly linked with outcomes concerning the disparities of relevant physical changes in environmental quality. In reality, this is not always the case. More often it is the main obstacle for which such comprehensive assessment cannot be done.

[12] These methods can be based either on revealed preferences, such as hedonic pricing, travel costs or averting behaviour expenditures, or stated preferences, such as contingent valuation or choice experiments. We are not, however, going to describe these methods in detail here as the recent economic literature, particularly in the field of environmental and resource economics, provides a good source if one is interested in their theoretical, methodological and conceptual aspects including practical applications. See also Ščasný and Melichar (2004) for a brief description of methods including a review of their applications in the Czech Republic.

IV.2.2 Method for analysing distributional effects due to environmental quality

Welfare assessment of changes due to environmental quality is complex problem requiring much more space than one chapter. We will therefore only discuss a method that could result in welfare measurement of such changes.

Let's assume there are goods that produce negative externality[13] during their consumption or production. Certain policy intervention is introduced in order to control externality, i.e. to reduce such negative effect by reducing the amount of such goods consumed.

Then, an assessment of welfare changes that would include their distributional aspects due to such policy intervention would require follow several steps.

- Firstly, one needs to estimate changes in consumption of goods that produce externality due to the policy intervention. In our case, one needs to know how consumption of energies would be reduced due to changes in (energy) taxes.
- Secondly, an appropriate method needs to be applied in order to quantify the physical impacts on affected receptors (people say) due to the change in quantity consumed. As we are concerned only on the externalities, only changes that affect production or utility function would be considered (see Ščasný-Havránek-Melichar, 2004). We also consider only externalities due to airborne pollution.
- As the distributional effects of changes in environmental quality are concerned, one needs to know how the change in consumption and ambient concentration affected various households or individuals. In other words, how are the physical effects, e.g. morbidity or premature mortality are distributed among the households or even among the individuals. If such information is not available, one can assume that the effects are distributed equally or just stop welfare analysis.
- Fourthly, the effects distributed among the individuals – even that one equally assumed - need to be properly monetary valued.

[13] Verhoef (2002, p. 200) defines externality as follows: "an external effect exists when actor's (the receptor's) utility (or production) function contains a real variable whose actual value depends on the behaviour of another actor (the supplier), who does not take this effect of his behaviour into account in his decision-making process". This definition is in line with a mainstream economic theory (for instance Mishan 1971; Scitovsky 1954). According to Mishan (1971, p. 2; in Verhoef 2002, p. 200), "the essential feature of an external effect [is] that the effect produced is not a deliberate creation but an unintended or incidental by-product of some otherwise legitimate activity".

IV.2.2.1 Changes in consumption of dirty goods

Change in consumption is explicitly predicted in our simulation model. Having data on demand responsiveness (price and income elasticity), one can easy predict changes in demand.

Table IV-10: Change in consumption of energy goods, the ETR.

	Coal	Gas	Heat	Electricity
	kg	GJ	GJ	kWh
Decil_1	-28.8	3.7	-4.1	-652.2
Decil_2	-16.4	2.2	-4.3	-668.0
Decil_3	-32.4	3.8	-5.0	-701.8
Decil_4	-30.6	3.6	-4.9	-795.6
Decil_5	-25.8	4.4	-5.4	-813.0
Decil_6	-31.0	4.2	-4.4	-783.5
Decil_7	-44.5	2.4	-4.5	-780.7
Decil_8	-25.4	4.0	-5.2	-908.3
Decil_9	-40.1	3.2	-5.7	-883.6
Decil_10	-18.7	5.2	-5.8	-943.2
ELECTRA	0	0	0	-743.4
ELEcookGAS	0	0.1	0	-860.9
HEATcookELE	0	0	-10.5	-1,181.5
HEATblocks	-1.6	17.4	-9.8	-1,201.3
GASheat	-8.8	-8.5	0	-354.4
COALheat	-288.8	0	0	-259.9
farmer_small	-105.5	-1.2	-0.2	-464.2
farmer_big	-52.7	-0.6	-2.3	-839.2
retired_small	-82.0	-4.9	-0.2	-410.3
retired_mid	-10.4	2.4	-3.2	-569.4
retired_big	-5.5	7.1	-6.1	-733.4
EA1_small	-32.1	-3.2	-0.4	-415.8
EA1_big	-4.8	4.9	-5.5	-680.8
EA1+_small	-95.7	-2.2	-0.6	-478.1
EA1+_big	-14.4	5.3	-6.4	-947.3
EA2_small	-80.7	-4.9	-0.7	-497.7
EA2_big	-23.6	5.6	-6.0	-914.9
EA2+_small	-126.8	-4.2	-0.3	-515.6
EA2+_big	-19.6	5.2	-6.6	-1,056.7
Total change – CZ	-123.4 kt	15.4 TJ	-20.7 TJ	-3,331 GWh
in % of before-tax level	-6.5%	+14.3%	-38.5%	-22.4%

Note: $t_{electricity}$=0.43 CZK/kWh plus heat 19%.

We consider the ETR policy variant, i.e. introducing the excise tax on coal (50% price increase), on gas (50% increase), and electricity (20%

increase) and shifting heat from 5% VAT towards to 19% VAT rate (with the effect of increased price of gas and coal used as the inputs, it would increase heat price by 43%). The ETR variant would reduce heat consumption as the most (by 38.5%), then electricity (-22%), while consumption of gas would be increased (+14%).

Reduction in consumption varies significantly among the household groups. These differences are however visible more in the household groups we compose for the purpose of this research rather than for the income clases. For instance, electricity is reduced as the most not in the households that use electricity for heating, as one would intuitively expect, but in the households that use electricity for cooking and in the households living in the block-of-flats. Consumption of coal is then reduced as the most in the households living in small municipalities, while there is almost none change in its consumption in big municipalities.

Indeed, due to the cross-price effects the tax reform design would indeed affect heavily a final fuel-mix. Increase in electricity tax only would reduce consumption of all non-durable energy goods. Electricity tax with a rate of 0.25 CZK per kWh (8.3 € per MWh) would reduce not only consumption of electricity by 4%, but reduce consumption of heat (11%) and gas (2.6%) and yield increase in consumption of coal (by 2%). If tax rate of 1 CZK per kWh of electricity (33 € per MWh) was introduced, increase in coal consumption would be 6%; for simulation results see Tables IV-12.

We therefore confirm a relatively strong positive substitution effect between coal and electricity meaning that coal demand increases w.r.t. price of electricity.

Table IV-11: Change in consumption of energy goods, electricity taxation (t=0.25 CZK/kWh).

	Electricity taxation (t_e=0.25 CZK/kWh)				Electricity taxation (t_e=1.00 CZK/kWh)			
	coal *kg*	gas *GJ*	heat *GJ*	electricity *kWh*	coal *kg*	gas *GJ*	heat *GJ*	electricity *kWh*
Decil_1	9.3	-0.5	-1.1	-129.8	29.7	-0.9	-3.2	-490.8
Decil_2	4.8	-0.7	-1.1	-132.3	15.3	-1.7	-3.2	-502.2
Decil_3	10.0	-0.6	-1.4	-124.7	31.7	-1.1	-3.8	-479.5
Decil_4	9.7	-0.6	-1.3	-147.3	30.7	-1.1	-3.6	-559.3
Decil_5	7.1	-0.6	-1.5	-123.7	22.6	-1.2	-4.1	-484.6
Decil_6	8.3	-0.6	-1.2	-167.2	26.3	-1.0	-3.4	-624.0
Decil_7	14.4	-0.9	-1.3	-150.8	45.7	-2.0	-3.5	-580.0
Decil_8	8.0	-0.7	-1.5	-144.4	25.4	-1.5	-4.0	-558.8
Decil_9	10.9	-0.9	-1.6	-140.9	34.6	-2.0	-4.4	-549.7
Decil_10	6.0	-0.6	-1.6	-150.3	19.1	-1.2	-4.5	-581.6
Total change–CZ	37.1 kt	-2.8 TJ	-5.7 TJ	-0.59TWh	118.1 kt	-5.7 TJ	-15.8 TJ	-2.27TWh
% of before-tax level	+2.0%	-2.6%	-10.7%	-4.0%	+6.2%	-5.3%	-29.5%	-15.3%

Other policy variants similarly decrease energy consumption and thus environmental burden. The *ECmin* variant would decrease consumption of all four non-durable energy goods, of electricity and heat as the most (by 7%), of gas and coal by 2%.

Heat19 would reduce consumption of heat by 11%, but also of electricity by 7%. Consumption of gas would be slightly increased (+4%), consumption of coal would remain unchanged.

The impacts of the ETR on consumption are reported above in Table IV-11. Revenue recycling would be further, but slightly, reduced consumption of four energy goods, while consumption of motor fuels due to the income effect would rise by almost 1%. Provision of social transfer would lower energy consumption even more, mainly on detriment of consumption of motor fuels that would further increase (by +2% under "ETR10,000"). We conclude that revenue recycling and/or provision of social compensation would have positive effect on car use and thus adverse effect on environmental quality.

Increase excise tax by 50% (Fuel50) would reduce consumption of motor fuels by 13%. One can however expect lower reduction in car use if measured by kilometres driven due to positive long-term effects on stock.

IV.2.2.2 Quantification of damages due to changes in ambient concentration

The ExternE method with its core the Impact Pathway Analysis presents one of the appropriate tool for quantifying the impacts due to changes in environmental quality such as changes in atmospheric deposition (see EC, 1995; 1999; 2000 a 2005). The ExternE method then yields marginal external costs per unit of production that can be used as a measure of welfare changes. Thanks to the research conducted by the Charles University Environment Center in Prague (Ščasný, Melichar et al., 2005), the effects, such as a number of increased respiratory symptoms, cardiovascular diseases, or premature deaths associated with airborne pollution form power sector and their monetary values are calculated.

Using then EcoSense software, this study yields the external costs for the Czech reference technologies generating electricity from coal as high as 1 CZK per kWh produced (2002 data), the externalities for heat generation burning natural gas are 20 to 34 CZK per GJ, or 61 CZK per GJ if heavy oils burnt, and 15 to 30 CZK per GJ if biomass burnt (see Tables IV-11 and Table IV-12).

Table IV-12a: The external costs of electricity generation per kWh.

	Hard coal	Brown coal	lignite (CHP)	Brown coal (CHP)
Mortality	0.19	0.34	0.32	0.27
Morbidity	0.10	0.17	0.15	0.12
Agriculture crop	-0.0020	-0.0038	-0.0014	-0.0023
Building materials	0.0164	0.0262	0.0330	0.0257
Climate change	0.59	0.63	0.70	0.72
Up-stream damages	0.1022	0.0235	0.0305	0.0217
Total externalities	0.99	1.18	1.23	1.16

Source: Charles University Environment Center in Ščasný, Melichar et al., 2005.

Table IV-12b: The external costs of heat generation per 1 GJ.

	Vřesová	**Karlovy Vary**	**Brno Červený Mlýn**	**Liberec**	**Bystřice**	**Trhové Sviny**	**Žlutice**
	energo-gas	gas	gas	heavy oils	biomass	biomass +gas	biomass
Fuel consumption, thousands m^3 / tones	1 150 440	4 201	61 029	43501	8 761	3 894	4 920
Mortality		10.36	1.60	21.19	10.54	13.56	20.26
Morbidity		4.10	0.66	9.78	4.93	6.51	9.52
Agriculture crop		-0.15	-0.02	-0.10	-0.06	-0.04	-0.10
Building materials		0.52	0.10	2.37	0.37	0.25	0.51
Climate change		18.78	17.27	27.19			
Total externalities	**0.35 kWh**	**33.61**	**19.61**	**60.86**	**15.78**	**20.28**	**30.19**

Source: Charles University Environment Center in Ščasný, Melichar et al., 2005.

Considering gas fuel inputs, we get the external costs about 40 CZK per 1 GJ of gas input.[14] Based on the externality assessment as one criterion, the Czech ETR proposal (MoE, 2005) sets out the relative rates for energy taxes for the year 2015 as high as 1,094 CZK per 1 GJ of brown coal, 17 CZK per 1 GJ of natural gas, and weighted rate by actual fuel-mix for electricity is 0.65 CZK per kWh.

We use arbitrary following values of the external costs for our experimental assessment:

- 0.65 CZK per 1 kWh of electricity consumed,
- 30 CZK per 1 GJ of heat generated,
- 20 CZK per 1 GJ of gas used to generate energy
- 1,000 CZK per 1 t of coal used (MoE, 2005)

There are however three caveats one should be aware:

[14] The externality associated with 1 GJ of gas input is higher than the externality associated with 1 GJ of heat generated from gas input as reported in Table IV-14 because the reference technologies are the cogenerations and thus also produced electricity from the gas inputs.

- the external costs associated with electricity consumed in the households heavily depend on the fuel-mix associated with the energy and heat generation;
- the external costs are site-, time-, and technology specific, therefore the externality values as calculated for big emission sources can be used only as a very rough proxies for the externality associated with energy generation in small (residential) sources;
- the external costs are

IV.2.2.3 Distribution of damage and welfare

As the distributional effects of changes in environmental quality are concerned, one needs to know how the change in consumption and ambient concentration affected various households or individuals. In other words, how are the physical effects, e.g. morbidity or premature mortality are distributed among the households or even among the individuals.

Ideally, one should calculate total welfare change due to changes in atmospheric concentration as follows:

$$W = \sum_{n}^{N} \sum_{i}^{I} V_{ni} \cdot Q_{ni} \quad \text{(IV-10)}$$

where **V** denotes to monetary valuation of impact i by individual *n*, **Q** is number of cases of each impact *n*, such as coughs, asthma attacks or statistical years or lives lost suffered by the individual *i* (it could be also a severity of the impact *i* or binary vector indicating whether an individual *n* was affected by the impact *i* or not), *I* is a vector of whatever possible impacts caused by environmental change and *N* denotes a number of country residents.

How are these impacts, e.g. asthma or heart attack, cough, and other minor respiratory diseases, or cases of premature death further distributed within the Czech population is unknown information.

Not having these data, we can just assume that the physical effects are distributed equally, i.e. assuming that the equality of exposure and risk notion of fairness is fully fulfilled. Then,

$$Q_{ni} = Q_i / N \quad \text{(IV-11)}$$

where Q_i is total physical effect *i* due to emission change given, for instance, as a result from the EcoSense software.

According to the study by Ščasný, Melichar et al. (2005), the damages have strong regional character, i.e. local impacts that affect only residents of the country present minor part of overall impact. According to the above study, the Czech residents suffer only 20% of the impacts on mortality and morbidity and 40% on building materials that are associated with brown coal power plant. They, however, suffer only less than 10% of mortality and morbidity impacts and about 15% of impacts on materials associated with hard coal power plant (due to the lower amount of particulates). Including social preference of the state authority for the impacts that affect the non-residents, one can rewrite the eq. IV-11 as:

$$W = \sum_{i}^{I}\left(\sum_{r}^{R} V_{ir} \cdot Q_i^r + \phi \cdot \sum_{f}^{F}\left[(V_{if} \cdot Q_i^f)\right]\right) \qquad \text{(IV-12)}$$

where

$$N = R + F \qquad \text{(IV-12')}$$

$$Q_i^r = (\alpha_i Q_i)/R \qquad \text{(IV-12'')}$$

$$Q_i^f = ((1-\alpha_i)Q_i)/F \qquad \text{(IV-12''')}$$

where *R* a *F* are numbers of residents of domestic country of the authority (say the Czech Republic), or of the residents living under the area affected by the atmospheric deposition except the considered country respectively, and ϕ reflects state authority's preference for the impacts outside of the country burdened on the foreigners (if $\phi = 1$, the foreigners are fully included in authority's social utility function). Q_i^r and Q_i^f are equally distributed effects that are obviously the same in each region (the Czech Republic and abroad). The share of the impact *i* that affects only the domestic (Czech) residents, α_i, depends *inter alia* on the share of fuels used, i.e. a component of particulates leading to more local impacts, atmospheric and climate conditions and the location of the emission sources.

For distributional analysis one may assume that $\phi = 0$, i.e. only country residents would be considered. The shares of α_i and a number of the effects Q_i like morbidity symptoms, number of statistical life-years lost or statistical lives could be provided by the EcoSense software that is using the ExternE method. Default monetary values for the impacts Q_i are also provided by the EcoSense, meaning the averages mostly for the EU-15.

For simplicity we assume that α equals to 0.20 for each impact and $\phi = 0$. The externality for each impact equals to $\sum_n V_n \cdot Q_n$, where V_n, i.e. valuation of impact, is the same for each individual *n*. Such values are directly given for each impact category by the EcoSense software tool. Following equation IV-10 and considering default monetary values, we would get marginal welfare change due to the change of one unit of consumption for all Czech residents and per one inhabitant as reported in Table.

Table IV-13: Default external benefits due to reduction in ambient concentration.

	All affected	Czech residents (α =0.20)	One Czech inhabitant
Electricity, CZK per kWh	0.65	0.13	1.27451 E-08
Heat, CZK per GJ	30.00	6.00	5.88235 E-07
Gas, CZK per GJ	20.00	4.00	3.92157 E-07
Coal, CZK per t	1,000.00	200.00	1.96078 E-05

Note: Magnitude of total externality as assumed above in Section IV.2.2.2.

Then, we get directly the external costs, total welfare change, due to change in atmospheric deposition associated to changed consumption. Considering the average changes in consumption of each energy good in each household group, we can provide the externality as provided by each household group from the change in consumption of each good as shown in Table IV-14.

For the ETR variant, the avoided externalities that affect only the Czech resident are estimated as high as 520 million CZK. However, if all externalities were considered, meaning also those that affect non-residents, the magnitude of the effect is 2.6 bln. CZK.

Total welfare loss would be therefore reduced by about 51 CZK under the ETR variant due to improved air quality.

We argued in Section IV.1.1.1 that if the dead-weight loss is positive, there is an economic loss and inefficiency due to a tax change concerned. However, possible environmental benefits and employment double dividend could the dis-efficiency lower or even overbalance getting overall welfare improving situation. As we derive the DWL for the ETR as high as 7.5 bln. CZK, the environmental benefits would not suffice to balance dis-efficiency due to energy tax introduced even if the impacts on non-residents were considered.

There could be another perspective on avoided externalities: how particular household groups contribute to their reduction. Looking at the Table IV-16, one can find that the magnitude of externalities avoided rises with household incomes (from 100 CZK per household in the 1st decile to

140 CZK for the household in the 10th decile)). The externality is avoided mostly in the households that use heat and cook by gas (216 CZK in HEATcookELE) and in block-of-flats (146 CZK in HEATblocks). On the other hand, the household that use gas for heating would avoid the lowest amount of externality as high as 82 CZK in average.

Table IV-14: Calculation of avoided externalities due to change in environmental quality, the externalities produced for the Czech residents in CZK by one households.

In CZK per a household	Coal	Gas	Heat	Electricity	Sum of energies
Decil_1	-5.8	15.0	-24.5	-84.8	-100.1
Decil_2	-3.3	8.7	-25.9	-86.8	-107.4
Decil_3	-6.5	15.0	-29.9	-91.2	-112.6
Decil_4	-6.1	14.5	-29.1	-103.4	-124.2
Decil_5	-5.2	17.7	-32.3	-105.7	-125.4
Decil_6	-6.2	16.6	-26.3	-101.9	-117.8
Decil_7	-8.9	9.4	-27.1	-101.5	-128.0
Decil_8	-5.1	16.0	-31.0	-118.1	-138.1
Decil_9	-8.0	12.7	-34.4	-114.9	-144.5
Decil_10	-3.7	20.8	-34.7	-122.6	-140.3
ELECTRA	0,0	0,0	0,0	-96,6	-96,6
ELEcookGAS	0,0	0,6	0,0	-111,9	-111,3
HEATcookELE	0,0	0,0	-62,8	-153,6	-216,4
HEATblocks	-0,3	69,5	-58,9	-156,2	-145,9
GASheat	-1,8	-34,1	0,0	-46,1	-81,9
COALheat	-57,8	0,0	0,0	-33,8	-91,6
farmer_small	-21,1	-5,0	-1,4	-60,3	-87,8
farmer_big	-10,5	-2,5	-13,9	-109,1	-136,0
retired_small	-16,4	-19,7	-1,2	-53,3	-90,6
retired_mid	-2,1	9,5	-19,3	-74,0	-85,9
retired_big	-1,1	28,5	-36,4	-95,3	-104,3
EA1_small	-6,4	-12,8	-2,4	-54,1	-75,7
EA1_big	-1,0	19,8	-32,8	-88,5	-102,5
EA1+_small	-19,1	-8,8	-3,9	-62,1	-93,9
EA1+_big	-2,9	21,1	-38,7	-123,2	-143,6
EA2_small	-16,1	-19,6	-4,4	-64,7	-104,8
EA2_big	-4,7	22,4	-36,3	-118,9	-137,6
EA2+_small	-25,4	-16,6	-1,8	-67,0	-110,8
EA2+_big	-3,9	20,9	-39,4	-137,4	-159,9
Total change, million CZK	-24.7	61.5	-124.0	-433.1	-520.23

Magnitude of avoided externalities also rises with the size of municipality where the household live. The household of farmers and pensioners living in small municipalities avoid the externality of the equivalent of 88 CZK and 90 CZK respectively, while these household living in big municipality would avoid the externality of 136 CZK, or 104 CZK respectively. This holds for the households of economic active too, while bigger household with non-economic active, children say, living in big municipality avoids the externality as the most (144 CZK in EA1+big, and 160 CZK in EA2+big). Singles, not retired, living in small municipalities would avoid the least volume of externality among all household groups.

IV.2.2.4 Preference for the environmental change

In the previous calculation of welfare effects we assumed in line with the EC CBA guideline that each individual had the same preference for the changes in environmental quality, i.e. in atmospheric deposition and thus there is no income adjustment of relevant welfare values. As discussed already in this thesis, this need not be the case.

Indeed, air pollution and climate change may cause many negative impacts. Since these impacts are quantified and thus monetary valued, effects on human health contribute to more than 90% of total external costs associated to energy generation. Moreover, from that, acute and chronic mortality effects – premature death -- contribute by about 60% to the total value of externality (EC, 2000; 2005). Considering that effect that dominates the externality value, we experiment with a valuation of mortality effects for the Czech Republic.

The aim of this Section is not, however, to adjust monetary value of the externalities, as only one impact component of total external costs are considered, i.e. mortality. The goal of this section is rather to discuss appropriate methodological approach that cold yield results for appropriate benefit value adjustments.

The ExternE method uses a value of a statistical life for any mortality effects assessment as recommended by the European Commission for conducting cost-benefit analysis, as high as 1 million €. The CBA Methodology Guideline of Clean Air for Europe Programme prepared by the DG Environment of European Commission suggests for a quantification of health damage linked to PM exposure for 2010 using 2.0 million € for chronic mortality implying 52,000 € as a value of life year lost, 75,000 € for acute mortality, and 1.5 million € for (acute) infant mortality (up to 11 months of child) (see Holland et al., 2004). There is no income or other adjustment in this benefit values assumed as, for instance, the US EPA guideline does or the economic theory would require.

We benefit here from the survey conducted by Charles University Environment Center in there cities of the Czech Republic, Prague, Brno and Ostrava in August and September 2004. The main goal of the survey was to derive a value of statistical life[15] (VSL) for the Czech Republic by eliciting willingness-to-pay for a reduction in own risk of dying by *X* in 1000 during next following 10 years from cardiovascular and respiratory diseases. The questionnaire, experimental design, sampling plan and data are documented in Alberini, Ščasný, Kohlová, 2005 and Alberini, Ščasný, et al. 2006.

Formally, we bring following model to estimate WTP for own risk reduction of dying:

$$WTP_i = \exp(x_i \beta + z_i \gamma) \cdot (\Delta R_i)^{\delta} \cdot \exp(\varepsilon_i) \qquad \text{(IV-13)}$$

where **x** is a vector of respondent's characteristics, *z* denotes experimental treatment (abstract versus medical treatment variant), and ΔR_i presents risk reduction. We then run regressions relating WTP to experimental treatment variables and individual characteristics of the respondents and use an accelerated life model with a Weibull baseline hazard[16]. ε is type I extreme value distribution. As we apply double-bounded dichotomous choice as the payment mechanism, we have a mix of continuous and interval-data observations. Our model is estimated by the maximum-likelihood method.

Formally, we regress:

$$\log WTP_i = x_i \beta + z_i \gamma + \delta \cdot \Delta R_i + \varepsilon_i \qquad \text{(IV-14)}$$

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[15] The VSL is the marginal value of a reduction in the risk of dying, and is therefore defined as the rate at which the people are prepared to trade off income for a risk reduction. Formally, assume that the individual's utility is U(*y*), where *y* is aggregate consumption, and that he has a probability *p* of dying at the end of this period. Assuming that the state-dependent utility of consumption when the individual is dead is zero, expected utility is equal to: $E(U) = (1-p)U(y)$. The VSL is defined as the rate at which an individual is prepared to trade off income for risk changes, while keeping expected utility the same: $VSL = \frac{dy}{dp} = \frac{1}{1-p}\frac{U(y)}{U'(y)}$.

Although the VSL is a derivative, in a contingent valuation survey individuals are asked to report their WTP for a specified finite risk chance ΔR. In practise VSL is thus computed by first estimating WTP for a specified risk reduction ΔR, then converted into an approximation to the VSL ≈ WTP/ΔR (Alberini and Krupnick, 2003).

This approach has been applied in the USA, Canada (Krupnick et al., 2000; Alberini et al., 2001), Italy, France and the UK (Markandya et al., 2004; Alberini-Hunt-Markandya, 2004c), Brasilia (Ortiz, 2005), Italy (Alberini-Chiabai-Nocella, 2006), Japan (Krupnick et al., 2006), Poland (Giergiczny, 2006), Taiwan, and China. Literature review provides Alberini (2004).

[16] Alberini, Ščasný et al. (2005) experimented with several two-parameter distributions of VSL, namely with Weibull, lognormal, exponential and linear finding that the first two ones fit the data best. See there also more about their model description.

The Value of a Statistical Life can be derived as:

$$meanVSL_i = meanWTP_i \cdot \frac{\Delta R_i}{1000} \cdot 10\,years \qquad \text{(IV-15)}$$

Where ΔR_i refers to a risk reduction the WTP was stated for. As Weibull model is used, mean and median WTP can be computed as:

$$meanVSL_i = \hat{\sigma}_i \times \Gamma(\frac{1}{\hat{\theta}} + 1) \quad \text{and} \quad medianVSL_i = \hat{\sigma}_i \cdot (-\ln(0.5))^{1/\hat{\sigma}} \qquad \text{(IV-16)}$$

where σ is a scale parameter of Weibull distribution of VSL, and $\Gamma(\bullet)$ is the gamma function, the hats denoting the maximum likelihood estimates.

Estimated coefficients are displayed below in Table showing on weak scope effect (by a positive coefficient for log Risk Reduction indicating an increasing WTP with a magnitude of risk reduction, but not proportionally). *VSL decreases with the size of the risk reduction; m*edian VSL equals to 1.9 million € (mean VSL=3.06 mil. €) for 1:1000 risk reduction, while VSL is as high as 0.49 million € (mean VSL=0.78 millio €) for 5:1000 risk reduction.

Table IV-15: Weibull interval data model of WTP.

Variable	coefficient	t statistic
Intercept	9.7089**	15.01
Log Risk Reduction	0.1476*	2.00
Income per household member	0.0031**	3.44
Male (dummy)	-0.0363	-0.38
College degree (dummy)	-0.066	-0.63
Married (dummy)	0.2981**	3.19
Children 12 (dummy)	-0.2748*	-2.10
At Risk (dummy)	0.0676	0.69
Prague (dummy)	0.1798	1.62
Brno (dummy)	-0.0535	-0.47
Weibull shape parameter	0.8987**	25.10

** estimate significant at 1%-level, and * at 5%-level.

Derived income elasticity of WTP for mean of net income per household member is as high as +0.33. The model by Alberini, Ščasný, et al. (2005; 2006) yields a coefficient for total net household income +0.0022 (s.e. 0.0005, with significance at 1% level) giving the income elasticity on VSL for mean household income as +0.54. This is in line with empirical literature in this field supported by Krupnick et al. (2006); see Section III.1 too.

The ExternE methodology 2005-update (EC, 2005), revises significantly approach for valuation of mortality effects due to airborne pollution benefiting from the NewExt project carried out during the years 2002—2003 (Markandya et al., 2004).

Instead of VSL, chronic mortality is calculated by using VOLY, a value of life year loss that is calculated directly form WTP for own risk reduction of dying by 5:1000 during next following 10 years. Calculation of VOLY for chronic mortality follows three steps. Firstly, WTP for risk reduction of dying is derived. Median is regarded as robust and more reliable estimates. Because a Weibull distribution fits data the best it gives

$$medianWTP = \exp(\beta_0 + \beta_1 * Y) \times [-\ln(0.5)]^{1/\hat{\sigma}} \qquad \text{(IV-17)}$$

and yields β_0 = 6,4648 (s.e. 0,126), β_1 = 0,0089 (s.e. 0,0029), $\hat{\sigma}$ =0,7014 (s.e.0,042), while Y is net household income in thousands of euro. A Weibull double-bounded model then pegs mean WTP at 1,052 € (s.e. 128.4) and median at WTP 465 € (s.e. 33.3) per year for each month of life expectancy gains.

Then, life expectancy gain that corresponds to risk reduction of dying being offered to a respondent of certain sex and age is derived following Rabl (2003). In the last step, WTP for life expectancy prolonged is calculated. Because in the survey the payments would be made every year for ten years, the total WTP figures for a life expectancy gain of one month are 10,520 € (mean) and 4,650 € (median) respectively. The implied VOLY are thus as high as 125,250 € (mean) and 55,800 € (median), respectively. VOLY for acute mortality is derived from the chronic one and results in 74,627 € (median), or 167,509 € (mean) respectively. The default rounded values for VOLY are then used as high as 50,000 € (chronic), or 75,000 € (acute) respectively.

We apply the ExternE 2005 approach in the Czech Republic. Firstly we apply benefit transfer function approach, then we derive own regression function following the approach of Markandya et al., 2004 and EC, 2005.

Application of benefit transfer function requires enter the Czech HBS data into eq. IV-14 (mean of 2004 household income is 270,000 CZK, median equals to 256,000 CZK). The model yields for 5:1000 β_0 = 7.891 (s.e. 0.323), β_1 = 0.0043 (s.e. 0.0013), $\hat{\sigma}$ =0.8446 (s.e. 0.0939), while mean household income is 255,530 CZK. Then, WTP for 5:1000 is estimated to be 875 € (mean) and 411 € (median). Following the steps of the ExternE methodology, we derive WTP for one month life expectancy that is 7,112 € (mean) and 3,338 € (median). For the average life expectancy gain, as proposed in EC (2005), we get VOLY for chronic mortality for the Czech republic as high as 85,348 € (mean) and 40,060 € (median). VOLY for acute mortality is calculated as high as 127,385 € (mean), or 59,791 €

(median). VOLY median values for the Czech Republic are thus about 72% of values as derived for the European pooled data.

Alternatively, we also derive own regression function for WTP following the NewExt approach. We estimate WTP model for each size of risk reduction of dying (from 1 to 12 in 1000) being offered to a respondent. The replicating the Externe 2005 approach, we derive a value of VOLYs for each specific risk reduction of dying. Weibull double-bounded model pegs mean and median WTP as shown in Table IV-18. VOLY for risk reduction by 5:1000 (if mean household income was used) is 24,391 € (mean), and 14,468 € (median) respectively. Value of VOLY due to the weak scope effect falls with the size of the risk reduction offered. Median VOLY for an average risk reduction offered (4:1000), however, equals to 20,304 €. Median values of VOLY are in this case only 26% (5:1000), or 36% respectively, of the European ones.

Table IV-16: Value of VOLY for derived WTP function for the Czech Rep.

Risk reduction by...	Income mean	WTP		VOLY	
		mean	median	mean	median
1	288,620	6,406	4,492	54,768	38,402
2	285,650	9,868	5,318	46,404	25,005
3	315,640	11,324	6,428	50,712	28,784
4	225,280	9,855	5,829	34,329	20,304
5	255,530	8,753	5,192	24,391	14,468
6	276,350	8,882	4,745	25,311	13,522
7	161,780	7,515	5,864	25,240	19,696
8	247,670	14,267	11,836	39,462	32,737
12	188,920	10,080	8,446	21,065	17,651

This partial research yields two conclusions: firsts, the values of VOLY tend to be lower than values given for the pooled data of three EU-15 countries (Markandya et al, 2004) as well as the recommended values by the EC. It results in even lowers welfare benefits due to the environmental change as calculated above. Secondly, willingness-to-pay for health effects and thus relevant benefits from avoided relevant impacts increases with wealth (income) of the households. As the richer tends to enjoy environmental benefits more than poorer households, the regressivity of the tax change found would be thus even more deepened.

V Conclusions

V.1 Summary of results

We have built a conceptual framework for welfare measurement of tax incidence due to the financial effects and the effects arising from changes in environmental quality in Section II. We have also argued that there are many driving forces that may enhance or reduce disparities in the distribution, with consumer behaviour, responsiveness and preferences being the most important ones.

Analyzing microeconomic data from the Household Budget Survey and defining household groups according to their consumer patterns, we have estimated the short-run demand system for residential energy and passenger transport demands. We have used the Almost Ideal Demand System to estimate specifically the demand for electricity, gas, heat and solid fuels separately for a total of 19 household groups, and the demand for motor fuels, rail, bus and urban public means of transport for 13 household groups respectively.

Our household demand modelling yields two benefits: Our method of estimating demands for the household groups classified according to their specific consumer patterns (proxied by their source of heating) confirms heterogeneity in consumer behaviour higher than that found for income classes and among the household groups classified according to the social status of the head of each household. Our approach therefore provides a more complex picture of consumer heterogeneity and consumer responses and thus more useful and policy-relevant information.

Secondly, our previous demand modelling did not result in statistically significant estimates of price and/or income effects for certain non-durable goods. Particularly, the previous research did not yield significant estimates of demand for coal - for which there were the largest shares of zero expenditures and consumption. Our present classification of the household groups overcomes this problem.

Our elasticity estimations are in line with findings provided by standard empirical literature on the subject and show some expected signs. We get slightly higher and more heterogeneous results compared to those that we estimated in our previous research using time series and macro data. We have found own price elasticity for heat as high as -0.84 and -1.22, while it amounts to -0.11 for coal. Own price elasticities for electricity have been estimated between -0.2 to-1.0, and the price responsiveness is higher in the household that uses electricity for heating. This corresponds to what one would expect intuitively: if the budget share for a concerned goods (say electricity) is low, the price-elasticity would be small as well. This has, however, not been confirmed for gas demand: while the own price elasticity for the households equipped with gas heaters is estimated as high as -0.9, it is -2.26 for the households that use gas only for cooking. We have found that this group comprises mostly pensioners and households in 5th to 7th deciles.

Income elasticity is the highest for gas used for cooking (+0.93) and electricity used also for heating (+0.35). In all cases, income elasticity for electricity is one of the highest among energies. The lowest income elasticity holds for heat in blocks-of-flats (+0.17) and for gas in households using gas for heating (+0.10). On the other hand, households living in blocks-of-flats (with centrally supplied heat) show the highest income elasticity for electricity of all the groups. The results for income elasticities for gas are even more intuitively plausible. Households equipped with gas heaters have much smaller elasticities than those that use gas only for cooking. Income elasticity has a negative sign only for gas used in blocks-of-flats. This result is similar to what we got for three deciles in the 2003 study. We therefore conclude that if these households became wealthier, they would either use more efficient gas stoves, or cook and eat less at home.

Although we have provided the average elasticities for each household group, we do control the effect of other variables in the household demand estimations, such as dummy for pensioners, farmers, big city and village, variables for electric appliances and devices, number of household members and economically active persons, flat surface or winter temperature.

Estimates of own price elasticities for transport demand yield relatively similar numbers, about -0.50, most of them lying between -0.40 and -0.60. This is in line with the estimations provided by the empirical literature on this subject. The elasticity estimations, however, differ among the household groups. We can find the highest price responsiveness to bus and rail prices in the households of pensioners, particularly those living in municipalities of above 2,000 inhabitants. The lowest price sensitivity of bus demand is estimated for singles in those municipalities (-0.19). For rail, the households of two economically active persons are the least price-sensitive (-0.42). Farmers living in bigger municipalities are the least sensitive to price changes of urban public transport (-0.4), while the pensioners living in medium-sized towns are the most price-sensitive (-0.64).

Price responsiveness differs the greatest for motor fuel demand. One of the largest degrees of price sensitivity in motor fuel demand is confirmed for the households of one economically active person living in cities above 2,000 inhabitants (-0.6). Farmers living in towns and cities are the least price-sensitive (-0.06). One of the highest own price elasticities for motor fuels also holds for pensioners living in medium-sized towns, while pensioners living in small and big municipalities have the lowest price responsiveness of all the household groups. Therefore, we can confirm significantly higher own price elasticities of motor fuels – similarly as we found in our previous research - only for one sub-group of pensioners.

One can find a difference in income elasticity outcomes if compared with general empirical evidence: we find all income elasticities for public transport services to be positive, which does not indicate their inferior character as the case is in Western Europe and the USA. This probably presents a special case of consumer behaviour in the former transition economy. Income elasticity for all analysed transport goods is the highest for motor fuels (+0.71) and the lowest for railways (+0.66). The income effect for all kinds of transport is then relatively the lowest in households of pensioners and the highest in households of economically active persons with more members (children). A more luxurious character of motor fuels than that of public transport is confirmed particularly for the economically active households.

Using results from the household demand estimations, we have carried out a tax incidence analysis for several policy options based on higher energy taxation. Overall, we have done a distributional analysis for four options of increased taxes on dirty goods – implementation of Directive 96/2003/EC on Energy Taxation (*"ECmin"*), taxing heat subject to standard VAT rate (*"Heat19"*), introducing rates on energy taxes as suggested in the Environmental Tax Reform as proposed by the Czech Ministry of the Environment in 2005 and 2006 ("ETR"), and increased excise tax on motor fuels (*"Fuel50"*). Then, we have analysed the effects of possible revenue recycling via lowering direct labour taxes (*"ETR_labour"*) or social and health insurance payments (*"ETR_insur"*) combined with or without lump-sum social transfers as high as 3,000 CZK, or 10,000 CZK to the most affected household (with more than 20% of energy expenses) respectively (marked as *"ETR3,000"* or *"ETR10,000"*).

In our analysis, we have found that the "ECmin" would yield the highest DWL and welfare losses per unit of additional tax revenues, while the "Heat19" brings additional revenues with the least DWL and welfare losses. Regarding their efficiency, the fuel taxation is slightly better-off than the energy taxation as suggested under the "ETR"; the "Fuel50" yields DWL of 0.62, while the "ETR," 0.68 per unit of additional tax revenue. Revenue recycling, however, reduces dis-efficiency.

Each policy option analysed reduces energy consumption, except the consumption of the environmentally more friendly gas. Revenue recycling increases energy consumption, particularly due to the income effect on motor fuels. Social transfers further increase energy consumption, particularly that of coal.

We conclude that there is no ETR policy option that would not result in efficiency losses, however, revenue recycling would reduce DWL by at least about 40% and welfare losses by 25% (in comparison to no recycling). The *"ETR"* would yield zero DWL only if labour taxation and public tax revenues were significantly reduced. Households' budgets can be sustained unchanged only with large welfare and dead-weight losses, but that would bring additional public revenues. Households' welfare can be unchanged only with a state budget deficit and DWL.

We further confirm very different impacts on expenditures, budgets and welfare among the household groups. For the "ETR" option, welfare losses decline with economic wealth (deciles). The welfare of households living in bigger municipalities, pensioners, households connected to centrally supplied heating and those that use solid fuels for heating, is most seriously affected. Pensioners living in big cities are the greatest losers of the policy of all the analysed groups.

Revenue recycling slightly increases energy expenditures and reduces welfare losses. Welfare losses are lowered more significantly particularly in the first four deciles if revenues are recycled via lowering insurance payments (the *"ETR_insur"* option). Lower regressivity of this option is also confirmed by the Suits and Gini indexes. Thanks to the interaction of direct labour taxation and the social and health insurance schemes, the *"ETR_insur"* increases net incomes of employees with monthly nominal wages lower than about 10,000 CZK more significantly than the *"ETR_labour"*. Welfare impacts are even positive in the last three, highest-income, deciles, in households that use gas for heating, and in households with at least two economically active persons thanks to having earnings from the labour market. Negative welfare effects are smaller in villages. The welfare of households connected to centrally supplied heating remains to be most negatively affected after revenue recycling.

Provision of lump-sum transfers further decreases the welfare losses of the first five deciles to the detriment of higher welfare losses of the wealthier households. Lump-sum transfers as high as 10,000 CZK per household with more than 20% of energy expenditures result in relatively evenly distributed welfare losses among the deciles, while the first (poorest) deciles benefit the most. The welfare of deciles 4 and 5 is negatively affected. The welfare of pensioners is affected the most, while social transfers of 10,000 CZK would not suffice to compensate the losses of households of pensioners living in big cities (over 20,000 inhabitants). Larger families with more members (children) living in bigger municipalities are the second sensitive group even after lump-sum social transfer provided. Although lump-sum transfers provided with simultaneous obligatory insurance payment cuts will lower the welfare losses of the poorer households more than if they were supplemented by cuts in the lowest labour tax rate, the welfare losses of pensioners and larger families living in bigger cities still remain.

Welfare effects due to increased motor fuel taxation are relatively equally distributed among the decile groups, while farmers and households living in villages are negatively affected the most.

Reduction in consumption varies among the household groups and, of course, among the policy scenarios. However, these differences are more perceptible in the household groups that we composed for the purpose of this research rather than for income classes. For instance, if the ETR variant is introduced (without revenue recycling) electricity consumption is reduced mostly in households that use electricity for cooking and in households living in blocks-of-flats (not in households that use electricity for heating). Consumption of coal is then reduced mostly in households living in small municipalities, while there is almost no change in bigger municipalities. Indeed, due to the cross-price effects, the tax reform design would affect heavily the final fuel mix. Increasing the electricity tax only would result in a reduction in all non-durable energy goods consumption except coal.

We also draw a conclusion from our sensitivity analysis: if no response of demand to price and income changes was assumed (and no elasticities were used), the welfare impacts, energy expenditures and predicted additional public revenues from the increased energy tax would be the highest. This is due to the energy demand being fully unresponsive to price effects. If properly estimated elasticities were used in tax incidence analyses, the impacts on public revenues would be the lowest. The reason lies in the interaction of a tax system within which a revenue loss from one tax item may be balanced by an increase in revenues from other tax items. This means that an increased excise tax on energies could yield additional tax revenues, but it could also lead to an increase in energy expenditures. Considering the household budget constraint, the increased excise tax would also result in lower consumption of the other goods. As these goods are taxed by value added tax, public finances would thus lose some revenues.

We conclude that the average elasticities could be conveniently applied in assessment of public finance effects if no drastic tax reform was introduced. The government authority should pay attention to using proper elasticities if predictions were made for more significant changes due to a policy intervention. One may, however, care about the elasticities used at any time if the distributional aspects of a policy were concerned.

Our investigation into preferences for avoiding adverse health effects brings the following conclusions: willingness–to-pay for health effects increases with the wealth (income) of the households. The more a wealthier household tends to benefit from a positive environmental change than a poorer one, the more the regressivity of the tax change deepens. Having calculated aggregate environmental benefits as high as

520 million CZK for the *"ETR"* option, however, the DWL of 7.5 bln. CZK can be hardly balanced off.

We also draw a general conclusion from our analysis: although each ETR option reduces consumption of dirty goods, bringing environmental benefits, such a reform would also yield adverse social effects and dis-efficiencies. Households of pensioners and larger families living in bigger cities would be the greatest losers of such policy. The government authority may therefore want to focus on them more specifically while designing the environmental tax reform.

V.2 Concluding remarks

A tax reform is welfare-improving if the aggregate benefits induced by the policy are positive. This thesis has addressed only part of the costs/benefits of a policy measure. To be comprehensive, an evaluation should compare our results with possible labour double dividend and with all environmental benefits properly quantified. We conjecture that households that would benefit the most from the employment dividend are located in the lowest decile classes. Then, a tax reform that boosts employment may reduce the regressivity due to energy taxation. However, as forcefully argued by Kaplow (2004), the employment dividend would be obtained only if the policy change favoured efficiency in the notorious equity-efficiency trade-off. Thus it is possible not to account for the employment dividend provided that the tax changes are so designed as to leave the equity-efficiency solution of the tax and social system unchanged (and this is always possible, for example by manipulating marginal effective tax rates).

There is another equity consideration often ignored in theoretical models. Most of such models assume that a change in consumption of dirty goods leads to an identical physical impact on the different income groups as we had to assume in section IV.2. For example, it is assumed that the different income groups are exposed to the same air pollution levels. However, as supported by empirical research mostly carried out in the US and the UK, this need not be a realistic assumption. One may conjecture that local pollution is distributed unequally in the sense that low income groups are exposed more to health damage. If this is also the case for the Czech Republic, the poor households will benefit more from the environmental quality improvement due to decreased consumption of energies and fuels, therefore the adverse social effects can be (partly) mitigated.

There is another source of limitations to our work: we have not included labour supply into the model as was done by e.g. Brännlund and Nordström (2004), and thus separability between labour supply and demand for non-durable goods cannot be explicitly tested.

Because we have not modelled either effects on labour supply or labour double dividend involved by labour taxation cuts, dead-weight loss would equal for all policy options that recycle revenues and/or include a part of revenues for provision of lump-sum social transfers. It is also the reason why the dead-weight loss calculation is overstated, hence the presence of its rather upper bound in our tax incidence analysis.

Where households are heterogeneous, one may weigh the total losses and gains of different households to decide the best policy strategy given the expressed goals. The problem follows: even if a policy creates a more equal distribution on average – viewed for instance at the mean in different income deciles – several low-income households still use a considerable amount of concerned goods. Due to e.g. an increase in energy taxes, these low-income households will be severely affected relatively to the size of their income. The distributional effects then depend heavily on how one weights these households against the other ones. We, however, have not used any weights in our distributional analysis, i.e. we use implicitly equal weight for each household.

Two useful statements for further distributional analysis can be made: Firstly, there are several competing notions of equity in the assessment of effects due to changes in environmental quality that yield different outcomes regarding distributional fairness. Since they could yield different outcomes for distributional analysis and for regulation as such, for instance, for the optimal tax, it is necessary to choose one that will be followed. For instance, physical approaches of fairness would require an equal distribution of exposure or risks. If the preference-based notion of equity was considered, fair distribution could be reached even for different (physical) levels of environmental quality distributed; it could be reached due to the balancing of the physical (risk) differences by differences in individuals' preferences for relevant environmental quality.

Secondly, (physical) disparities given by following physical approaches cannot be directly joined to welfare analysis of financial effects. On the contrary, the outcomes provided by the preference-based analysis can be linked with the financial effects assessment. It would, however, require linking both results of distributional disparities both in physical impacts and in their preferences. This is not usually satisfied for many reasons. Thanks to that, a comprehensive welfare assessment can hardly be done. Due to lack of data and relevant analyses in the Czech Republic, this has also been a real obstacle in providing a comprehensive welfare assessment in this thesis.

The important caveat remains: the analysis presented in Section III of this thesis is short-run. Ščasný and Brůha (2005) also analyze the long-run energy demand in the Czech Republic. They use a dynamic econometric model of partial adjustment for 'the desired' composition of energy appliances. This desired, but unobservable, composition of appliances is influenced by household location, relative energy prices, and other factors. They assume that there is an incomplete adjustment of the actual composition of energy appliances since the households are liquidity-constrained. They apply a variant of a Gibbs sampler to estimate this model with the latent process of the desired composition: the estimated parameters are determinants of the desired composition and the adjustment speed, which may vary across households. They find that the lowest adjustment speed holds for households of pensioners and for larger families with children living in big cities. It was precisely these two groups that were the most sensitive ones proved in our distributional assessment as provided in Section IV of this thesis. That indicates that the government authority may want to pay special attention to them if social impacts dominate a policy decision. Moreover, researchers may want to target their efforts at more targeted demand analysis of these two household groups and a distributional assessment of possible policy compensating measures in their future research.

There are several more interesting and useful topics to be concerned in further research. Proper assessment of distribution in environmental quality and/or its changes would certainly be one of the first and foremost. Apart from the issue of environmental benefit disparities, there are two more topics to be improved in this field. The first one would aim at including the indirect financial effects due to a public intervention, particularly those arising from the labour market. As our modelling of parameters of labour taxation refers to the 2004 scheme, the model can be updated in respect of the last legislative changes in labour taxation as well.

There are many topics to be analysed and/or re-considered in household demand modelling. Several particular topics refer directly to our research: the first one refers to the inclusion of labour supply in the model in order to analyse its separability from demand for non-durable goods; the second one refers to considering only a variable part of energy prices in modelling, i.e. to separate the fixed and variable parts of energy tariffs; the third one calls for more proper estimation of household demand systems by e.g. classifying new household groups, by controlling other variables, and/or by using new datasets. Estimation of household demand in the long run would obviously follow. I encourage all of you to improve on, extend or update the analysis provided in this thesis. I am looking forward to discussing your results in near future.

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Appendix

Figure AIII-1: Energy and transport prices.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CPI	59,8	66,1	72,2	78,5	85,2	94,2	96,2	100	104,7	106,6	106,7	109,7
Natural gas, Kč/m^3	2,94	3,06	3,30	3,59	4,15	5,91	6,64	8,09	9,97	9,93	10,21	10,42
Brown coal, Kč/t	727,2	804	939	1037,3	1202,8	1500,5	1613,4	1670,7	1630	1708,5	1721,5	1720
Heat, Kč/GJ	119,23	137,72	161,66	178,4	239,71	291,86	300,22	314,11	334,65	334,83	338,67	343,6
Electricity, Kč/kWh	0,823	0,817	0,855	0,925	1,07	1,384	1,798	2,021	2,34	2,603	2,65	2,6
Rail – shadow price		0,0108	0,0156	0,0194	0,0214	0,0291	0,0318	0,0314	0,0333	0,0386	0,0372	
Bus – shadow price		0,0286	0,0336	0,0478	0,0536	0,0538	0,0547	0,0554	0,0519	0,0566	0,0578	
MHD – shadow price	0,0188	0,0208	0,0244	0,0278	0,0307	0,0364	0,0360	0,0365	0,0352	0,0349	0,0389	
Petrol (Natural 95)	19,02	19,49	19,28	20,42	22,01	21,90	23,12	28,80	27,27	24,45	24,55	
Diesel	15,80	15,63	15,66	16,65	18,77	18,04	18,99	24,75	24,07	21,73	21,89	24,92
Weighted motor fuels	18,41	18,90	18,84	19,89	21,37	21,37	22,44	28,03	26,62	23,96	24,05	26,08

Figure AIII-2: Financial situation of the households in HBS sample, in CZK (2000).

	income	pincome	expenses	expinc	savings	withdraws	withd inc	netsavingsinc
1993	189 771	76 414	182 248	0.97	33 266	30 189	0.15	0.02
1994	192 955	78 499	183 685	0.97	36 255	31 713	0.15	0.02
1995	205 441	84 655	195 518	0.97	47 394	41 323	0.18	0.03
1996	218 002	90 018	208 392	0.97	61 339	55 739	0.23	0.03
1997	219 463	91 355	215 145	0.98	67 556	65 619	0.26	0.01
1998	213 360	90 139	206 559	0.98	73 947	68 221	0.29	0.03
1999	221 493	94 243	215 458	0.98	85 462	81 130	0.33	0.02
2000	218 756	94 080	209 363	0.97	96 529	88 517	0.37	0.04
2001	224 764	96 298	211 019	0.96	108 396	98 369	0.40	0.04
2002	226 158	98 344	211 390	0.95	115 066	103 469	0.42	0.05
2003	240 290	104 358	224 006	0.95	130 566	117 589	0.45	0.05
2004	246 342	106 238	225 756	0.94	141 639	123 744	0.47	0.07

income = total yearly net income of household
pincome = net income per household member (per person a year)
expenses = total yearly net household expenditures
expinc = total net expenditures as a share on total net income
withdinc = bank withdrawals divided by net income
netsavingsinc = net savings divided by net income

Figure AIII-3: Sample description for the household energy demand analysis.

	Data type		ELEKTRINA	ELE cookGAS	HEAT cookELE	HEAT blocks	GASheat	COALheat
N			880	160	1 455	4 820	4 530	1 496
size of the city	numeric (1 to 9) 9=biggest	Mean	3.96	6.53	6.96	7.67	5.84	3.16
		Std	2.55	2.61	1.87	1.29	2.59	2.24
living in village	dummy	Mean	0.53	0.18	0.05	0.01	0.25	0.66
		Std	0.50	0.38	0.21	0.10	0.43	0.47
household members	continuous (number)	Mean	2.85	2.11	2.30	2.52	2.70	2.91
		Std	1.26	1.13	1.22	1.21	1.21	1.21
economically active persons	continuous (number)	Mean	1.42	1.13	1.15	1.26	1.33	1.46
		Std	0.80	0.83	0.80	0.85	0.83	0.82
number of children	continuous (number)	Mean	0.98	0.44	0.69	0.76	0.84	0.93
		Std	1.03	0.79	0.88	0.95	0.96	1.04
household of farmer	dummy	Mean	0.25	0.11	0.04	0.02	0.09	0.28
		Std	0.43	0.32	0.20	0.13	0.29	0.45
household of pensioners	dummy	Mean	0.14	0.28	0.22	0.22	0.19	0.15
		Std	0.35	0.45	0.42	0.41	0.39	0.36
age of head	continuous (years)	Mean	45.24	54.69	47.57	49.41	49.00	47.69
		Std	14.19	14.37	15.68	14.73	14.23	13.20
gender of the head	Dummy (male=1)	Mean	0.84	0.62	0.62	0.71	0.80	0.89
		Std	0.37	0.49	0.48	0.45	0.40	0.32
average education	numeric (1 to 6); 6=MSc. up	Mean	3.12	2.97	2.82	3.12	3.28	3.16
		Std	1.03	1.34	1.14	1.16	1.14	0.94
highest education	numeric (1 to 6); 6=MSc. up	Mean	3.74	3.93	3.85	4.00	4.01	3.67
		Std	0.92	1.03	0.99	1.00	1.02	0.85
university decree	dummy	Mean	0.11	0.16	0.14	0.17	0.18	0.07
		Std	0.31	0.36	0.34	0.38	0.38	0.26
rental house	dummy	Mean	0.18	0.23	0.44	0.34	0.22	0.09
		Std	0.38	0.42	0.50	0.47	0.41	0.29
private house/flat	dummy	Mean	0.68	0.74	0.55	0.66	0.69	0.80
		Std	0.47	0.44	0.50	0.47	0.46	0.40
year of construction	numeric (1 to 6) 1= before year 1946	Mean	3.10	2.11	4.03	3.65	2.62	3.08
		Std	1.81	1.53	1.25	1.08	1.72	1.75
detached house	dummy	Mean	0.39	0.38	0.00	0.00	0.34	0.57
		Std	0.49	0.49	0.00	0.00	0.47	0.50
terraced house	dummy	Mean	0.31	0.24	0.01	0.00	0.25	0.29
		Std	0.46	0.43	0.09	0.03	0.43	0.45
flat surface	continuous (numeric)	Mean	59.27	54.31	37.71	41.49	60.68	65.08
		Std	25.26	25.06	16.11	12.25	25.70	24.83
electric devices	continuous (number)	Mean	3.64	3.38	2.99	3.18	3.57	3.90
		Std	1.15	1.15	1.14	1.08	1.16	1.15
electric equipment	continuous (number)	Mean	1.79	1.74	1.74	1.95	1.98	1.74
		Std	1.06	1.22	1.12	1.18	1.20	1.04
net income	thousands CZK (2000prices)	Mean	225.9	196.4	207.2	230.7	238.4	234.7
		Std	98.0	104.4	112.1	113.3	118.7	107.3
net expense	thousands CZK (2000prices)	Mean	205.8	179.3	193.5	215.3	225.9	215.8
		Std	95.2	94.9	112.7	118.4	133.5	110.1
energy expenditures	% total expenditures	Mean	0.09	0.13	0.12	0.12	0.12	0.10
		Std	0.06	0.06	0.05	0.05	0.06	0.05

Figure AIII-4: Descriptive statistics for the household groups in transport demand model (2000—2004).

Social status			farmer	farmer	retired	retired	retired	ea1	ea1	ea1+	ea1+	ea2	ea2	ea2+	ea2+
Size of the city			small	big	small	medium	big	small	big	small	big	small	big	small	big
N			918	461	502	623	1,760	134	1,320	572	2,490	259	1,440	793	3,426
%			6.2%	3.1%	3.4%	4.2%	12.0%	0.9%	9.0%	3.9%	16.9%	1.8%	9.8%	5.4%	23.3%
size of the city	numeric (1to9) 9=biggest	Mean	1.89	5.44	2.19	5.14	8.03	2.00	7.69	2.18	7.24	2.19	7.23	2.06	7.30
		Std	0.83	1.44	0.79	0.87	0.82	0.81	1.45	0.83	1.65	0.79	1.55	0.83	1.60
living in village	dummy	Mean	1	0	1	0	0	1	0	1	0	1	0	1	0
		Std	0	0	0	0	0	0	0	0	0	0	0	0	0
household members	Ccntinous (number)	Mean	3	3.19	1.6	1.51	1.43	1	1	3.26	3	2	2	3.81	3.74
		Std	1.22	1.24	0.52	0.5	0.5	0	0	1.03	1.01	0	0	0.69	0.64
economically active persons	continous (number)	Mean	1.71	1.66	0	0	0	1	1	1	1	2	2	2.11	2.13
		Std	0.56	0.53	0	0	0	0	0	0	0	0	0	0.37	0.38
number of children	continous (number)	Mean	1.02	1.22	0.01	0	0	0	0	1.35	1.25	0	0	1.62	1.51
		Std	1.08	1.07	0.09	0.04	0.02	0	0	0.96	0.92	0.03	0.01	0.86	0.76
university decree	dummy	Mean	0.08	0.19	0.05	0.06	0.11	0.03	0.10	0.13	0.18	0.09	0.15	0.12	0.24
		Std	0.27	0.39	0.21	0.25	0.32	0.17	0.30	0.33	0.38	0.29	0.36	0.33	0.43
detached house	dummy	Mean	0.47	0.37	0.59	0.25	0.09	0.49	0.06	0.44	0.11	0.49	0.16	0.54	0.15
		Std	0.50	0.48	0.49	0.43	0.29	0.50	0.24	0.50	0.32	0.50	0.37	0.50	0.36
terraced house	dummy	Mean	0.28	0.21	0.26	0.19	0.08	0.33	0.05	0.32	0.11	0.24	0.11	0.32	0.12
		Std	0.45	0.41	0.44	0.39	0.27	0.47	0.22	0.47	0.31	0.43	0.31	0.47	0.32
net income	CZK (2000prices)	Mean	90,890	90,925	79,123	78,654	81,726	123,463	141,359	90,606	96,134	127,931	138,738	82,652	91,957
		Std	34,804	37,581	14,394	13,118	15,634	46,911	52,565	49,710	43,947	44,172	43,808	26,264	36,039
net expense	CZK (2000prices)	Mean	215,253	243,665	124,050	116,452	115,346	126,423	133,817	214,737	217,833	234,208	247,983	274,706	302,055
		Std	90,739	111,479	50,046	46,922	51,192	82,437	61,449	160,300	103,438	101,169	114,959	105,296	141,088
car vintage	continuous (number)	Mean	12.47	10.45	14.53	15.23	15.69	11.92	11.29	10.67	10.55	10.62	9.93	10.26	9.75
		Std	7.65	7	7.36	7.42	8.19	7.24	7.55	7.6	7.23	7.05	7.17	7.29	6.65
does not own car	dummy	Mean	0.15	0.19	0.55	0.58	0.68	0.60	0.72	0.22	0.40	0.15	0.20	0.09	0.16
		Std	0.36	0.39	0.50	0.49	0.47	0.49	0.45	0.41	0.49	0.36	0.40	0.29	0.37
number of cars	number of cars	Mean	0.93	0.93	0.48	0.43	0.33	0.45	0.28	0.88	0.65	0.92	0.90	1.07	0.95
		Std	0.48	0.55	0.55	0.51	0.48	0.60	0.46	0.55	0.57	0.51	0.56	0.52	0.53
transport expenditures	% on total expenses	Mean	0.07	0.06	0.04	0.03	0.03	0.07	0.04	0.07	0.05	0.07	0.06	0.08	0.06
		Std	0.04	0.04	0.04	0.04	0.03	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03
expenditures on public transport	% on total expenses	Mean	0.02	0.02	0.01	0.01	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02
		Std	0.02	0.02	0.01	0.01	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02
transport expenditures	CZK (2000prices)	Mean	14,103	15,342	5,297	4,440	3,663	8,304	5,674	14,050	10,878	16,009	14,242	20,848	17,335
		Std	9,066	9,907	5,851	4,940	4,573	5,966	5,954	8,505	8,608	9,135	9,522	10,238	10,633
expenditures on public transport	CZK (2000prices)	Mean	3,459	3,795	854	751	1,149	2,802	2,649	2,889	3,119	3,782	3,169	5,816	5,050
		Std	4,655	5,370	1,069	1,047	1,375	3,203	2,819	3,842	3,714	3,834	3,752	6,099	5,227
vehicle expenditures	CZK (2000prices)	Mean	19,759	21,865	6,737	5,611	3,827	8,678	5,851	18,263	14,779	23,309	22,715	25,781	22,122
		Std	40,623	41,737	17,425	18,354	15,491	25,036	24,444	32,366	37,455	43,234	50,821	45,173	43,756
fuel expenditures	CZK (2000prices)	Mean	10,644	11,492	4,351	3,672	2,477	5,292	2,822	11,161	7,670	12,105	10,896	14,954	12,095
		Std	7,040	8,258	5,754	4,932	4,184	5,920	5,528	8,540	8,514	9,053	8,740	9,147	9,520
city-public transport expenditures	CZK (2000prices)	Mean	159	409	120	129	692	406	1,441	520	1,601	459	1,738	885	2,596
		Std	625	942	468	344	1,044	1,049	1,731	1,507	2,365	1,219	2,389	2,264	3,310
bus expenditures	CZK (2000prices)	Mean	2,818	2,586	564	412	232	2,131	765	1,874	963	2,677	937	3,975	1,607
		Std	4,062	4,577	737	680	544	2,713	1,878	3,076	2,131	3,068	2,061	4,979	3,515
rail expenditures	CZK (2000prices)	Mean	482	799	170	210	225	265	443	495	554	647	494	956	847
		Std	1,605	2,089	392	504	519	652	1,081	1,323	1,561	2,089	1,573	2,210	2,140
vehicle expenditures	CZK (2000prices)	Mean	7,646	8,932	1,827	1,546	1,015	2,926	2,733	5,642	6,079	9,536	10,257	8,681	8,394
		Std	38,702	39,654	15,135	16,981	14,126	22,913	22,765	29,433	34,259	41,259	48,570	42,413	41,268

Figure AIII-5: Ownership of passenger cars, in % of all households within the group.

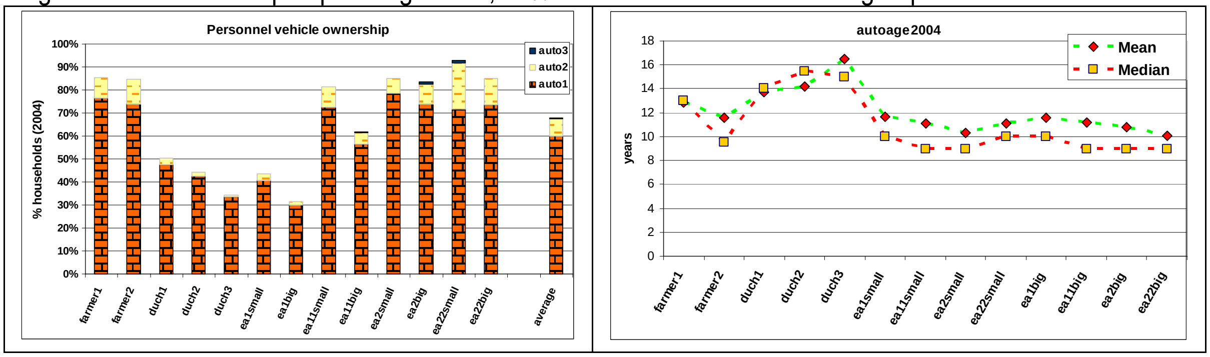

Figure AIII-6a: Energy expenditures as a share of net expenditures, HBS-2004.

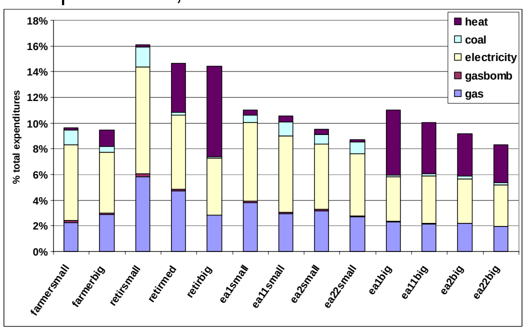

Figure AIII-6b: Composition of energy expenditures, HBS-2004.

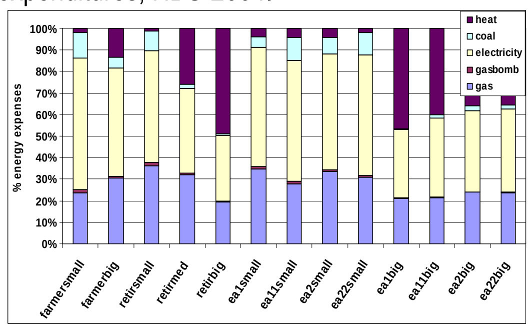

Figure AIII-7: The household group distribution in income deciles, HBS 2000—2004, in % of the group.

Household groups	Income deciles									
	decil_1	decil_2	decil_3	decil_4	decil_5	decil_6	decil_7	decil_8	decil_9	decil_10
Farm_small	22	14	8	6	5	6	7	11	15	7
Farm_big	21	15	8	7	5	10	8	7	9	9
Pens_small	3	13	17	21	17	18	8	3	0	0
Pens_med	2	8	21	22	20	17	7	2	1	0
Pens_big	2	7	16	20	20	16	12	5	1	0
EA1small	3	1	1	4	3	13	12	19	20	24
EA1big	0	1	2	2	3	4	7	14	26	40
EA1+small	37	17	9	6	6	4	9	6	3	3
EA1+big	26	17	9	6	6	8	8	9	7	5
EA2small	0	2	1	2	2	7	12	20	27	27
EA2big	0	1	0	1	2	3	8	16	30	38
EA2+small	15	16	11	9	11	8	9	10	8	3
EA2+big	9	11	10	8	9	11	13	13	9	6
ELECTRA	20	12	9	9	8	8	8	11	8	9
ELEcookGAS	6	7	9	8	12	10	16	8	16	8
HEATcookELE	9	10	10	10	8	8	9	9	11	15
HEATblocks	9	9	9	9	10	10	10	10	12	13
GASheat	11	10	9	8	9	9	11	12	11	10
COALheat	16	13	11	9	8	8	10	9	10	6

The results of household energy demand system modelling – the household groups classified according to the heating source considered

This appendix contains the detailed results of energy demand system estimation. The parameters correspond to parameters regression equation in the main text.

GROUP 1 – ELEKTRINA

Parameter	*Point estimation*	P-value
γ_{11}	0.0257	0.30
α_{10}	0.5151	0.00
α_{11} surface	0.0004	0.00
α_{12} ele_devices	0.0034	0.00
α_{13} winter temperature	-0.0014	0.32
α_{14} dummy for pensioner	0.6946	0.00
α_{15} dummy for farmer	0.3086	0.04
β_{10}	-0.0417	0.00
β_{11} dummy for pensioner	-0.0631	0.00
β_{12} dummy for farmer	-0.0288	0.04
$\alpha 0$	0.0008	0.78

The demand system consists of electricity and other goods.

GROUP 2 – ELEcookGAS

Parameter	*Point estimation*	P-value
γ_{11}	-0.0120	0.86
γ_{12}	0.0575	0.02
α_{10}	0.2462	0.00
α_{11} surface	0.0004	0.00
α_{12} number of persons	-0.0033	0.00
α_{13} winter temperature	-0.0105	0.04
β_{10}	-0.0252	0.00
γ_{22}	-0.3226	0.00
α_{20}	0.9693	0.00
α_{21} winter temperature	0.0129	0.00
α_{22} number of children	-0.0017	0.58
b20	-0.0317	0.00
α_0	-0.0008	0.78

The demand system consists of electricity (indexed by 1), gas (indexed by 2) and other goods.

GROUP 3 - HEATcookELE

Parameter	*Point estimation*	P-value
γ_{11}	0.0285	0.02
γ_{12}	-0.0586	0.10
α_{10}	0.5624	0.00
α_{11} number of persons	0.0037	0.00
α_{12} ele devices	0.0028	0.00
β_{10}	-0.0271	0.00
β_{11} dummy for a big city	-0.0003	0.02
γ_{22}	-0.0156	0.92
α_{20}	0.6590	0.26
α_{21} winter temperature	-0.0055	0.02
α_{22} flat surface	0.0006	0.00
α_{23} number of persons	0.0036	0.00
α_{24} number of economic active persons	-0.0064	0.00
β_{20}	-0.0548	0.00
β_{21} dummy for a big city	0.0012	0.00
α_0	0.0021	0.74

The demand system consists of electricity (indexed by 1), heat (indexed by 2) and other goods.

GROUP4 - HEATblocks

Parameter	*Point estimation*	P-value
γ_{11}	0.0191	0.04
γ_{12}	0.0145	0.00
γ_{13}	-0.0861	0.00
α_{10}	0.5596	0.00
α_{11} number of persons	0.0010	0.26
α_{12} ele devices	0.0029	0.11
β_{10}	-0.0170	0.00
γ_{22}	-0.0289	0.00
γ_{23}	0.0629	0.00
α_{20}	-0.2731	0.00
α_{21} number of persons	0.0000	0.12
β_{20}	-0.0056	0.00
γ_{33}	-0.0694	0.33
α_{30}	1.9049	0.00
α_{31} winter temperature	-0.0043	0.02
α_{32} flat surface	0.0007	0.00
α_{33} dummy for pensioner	0.0029	0.12
β_{30}	-0.0611	0.00
α_0	0.0006	0.33

The demand system consists of electricity (indexed by 1), gas (indexed by 2), heat (indexed by 3) and other goods.

GROUP 5 - GASheat

Parameter	*Point estimation*	P-value
γ_{11}	0.0312	0.01
γ_{12}	-0.0374	0.00
α_{10}	0.3964	0.00
α_{11} number of persons	0.0059	0.09
α_{12} ele devices	0.0048	0.08
β_{10}	-0.0330	0.00
γ_{22}	-0.2256	0.00
α_{20}	1.1422	0.00
α_{21} time trend	0.0094	0.01
α_{22} flat surface	0.0003	0.03
α_{23} number of economic active persons	-0.0021	0.20
α_{24} dummy for pensiner	0.0139	0.25
β_{20}	-0.0600	0.00
α_{0}	0.0001	0.40

The demand system consists of electricity (indexed by 1), gas (indexed by 2) and other goods.

GROUP 6 - COALheat

Parameter	*Point estimation*	P-value
γ_{11}	0.0291	0.0586
γ_{12}	0.0064	0.0024
α_{10}	0.3770	0.0000
α_{11} number of persons	0.0025	0.1176
α_{12} ele devices	0.0011	0.1688
α_{13} dummy for villages	0.0027	0.1489
β_{10}	-0.0381	0.0000
γ_{22}	0.0262	0.0000
α_{20}	0.0753	0.0000
α_{21} winter temperature	-0.0009	0.1329
α_{22} flat surface	0.0001	0.0859
α_{23} dummy for pensioner	0.0090	0.1726
α_{24} dummy for villages	-0.0046	0.1822
β_{20}	-0.0232	0.0000
α_{0}	0.0020	0.3320

The demand system consists of electricity (indexed by 1), solid fuels (indexed by 2) and other goods.

The results for the energy demand for the 13 household groups classified according to the social status and the municipality size

Uncompensated (Marshallian) price elasticities (own prices elasticities are shaded)

Household group	Uncompensated price elasticity of ELECTRICITY demand with respect to price of				Uncompensated price elasticity of SOLID FUELS demand with respect to price of			
	Electricity	Gas	Heat	Solid fuels	Electricity	Gas	Heat	Solid fuels
Farmer (villages)	-0.52	-0.02		-0.04				
Farmer (cities)	-0.54	0.04		0.06				
Pensioners (villages)	-0.54	-0.03		-0.02				
Pensioners (small cities)	-0.57	0.13	0.09	0.13		-0.02	-0.41	
Pensioners (bigger cities)	-0.84	0.2	0.14	0.21		-0.04	-0.63	
EA1 (villages)	-0.49	0.04		-0.02				
EA1+ (villages)	-0.57	-0.05		0.08				
EA2 (villages)	-0.56	-0.18		-0.04				
EA2+ (villages)	-0.45	0.2		-0.04				
EA1 (cities)	-0.64	0.11	0.16	0.05		-0.02	-0.47	
EA1+ (cities)	-0.65	0.14	0.1	0.15		-0.02	-0.45	
EA2 (cities)	-0.61	0.15	0.1	0.14		-0.02	-0.46	
EA2+ (cities)	-0.65	0.14	0.1	0.15	-0.03	-0.02	-0.47	-0.03
Weighted average	-0.632	0.115	0.113	0.108	-0.030	-0.023	-0.486	-0.030

Household group	Uncompensated price elasticity of GAS demand with respect to price of				Uncompensated price elasticity of HEAT demand with respect to price of			
	Electricity	Gas	Heat	Solid fuels	Electricity	Gas	Heat	Solid fuels
Farmer (villages)	0.12	-0.43		0.34	0.02	0.24		-0.51
Farmer (cities)	-0.05	-0.39		0.22	-0.05	0.21		-0.49
Pensioners (villages)	-0.05	-0.42		0.24	-0.02	0.31		-0.45
Pensioners (small cities)	0.14	-0.45	0.12	0.08	0.08	0.25		-0.35
Pensioners (bigger cities)	0.23	-0.56	0.16	0.11	0.11	0.36		-0.5
EA1 (villages)	0.15	-0.46		0.41	-0.07	0.28		-0.54
EA1+ (villages)	0.12	-0.27		0.27	-0.1	0.19		-0.58
EA2 (villages)	0.04	-0.34		0.34	0.04	0.24		-0.57
EA2+ (villages)	0.15	-0.21		0.2	-0.08	0.24		-0.44
EA1 (cities)	0.15	-0.51	0.14	0.08	0.09	0		-0.42
EA1+ (cities)	0.15	-0.51	0.13	0.09	0.09	0.27		-0.4
EA2 (cities)	0.16	-0.48	0.13	0.09	0.09	0.28		-0.4
EA2+ (cities)	0.16	-0.49	0.14	0.09	0.09	0.28		-0.4
Weighted average	0.144	-0.465	0.139	0.136	0.061	0.276	0.000	-0.436

Income elasticities. median:

Household group	Electricity	Gas	Heat	Solid fuels (coal)
Farmer (villages)	0.98	0.84		0.9
Farmer (cities)	0.94	0.78		0.87
Pensioners (villages)	0.74	0.58		0.87
Pensioners (small cities)	0.71	0.62	0.58	0.44
Pensioners (bigger cities)	0.9	0.85	0.95	0.56
EA1 (villages)	0.96	0.86		0.87
EA1+ (villages)	1.01	0.81		0.93
EA2 (villages)	0.91	0.79		0.84
EA2+ (villages)	1.08	0.91		0.94
EA1 (cities)	1	0.79	0.64	0.69
EA1+ (cities)	1.08	0.82	0.76	0.78
EA2 (cities)	0.77	0.7	0.66	0.47
EA2+ (cities)	0.76	0.66	0.63	0.48
Weighted average	0.902	0.759	0.712	0.661

Figure AIV-1: Model simulation for revenues from labour taxation and insurance, 2004.

	HBS data				Wage model simulation: reference scenario			
	Wages and salaries	Revenues from business	Retirement pension	Social allowances	Tax-base for labour taxation	Insurance paid by employees	Labour taxes paid by employees	Insurance paid by employers
1decil	153,824	31,582	5,532	45,483	130,472	26,104	20,634	65,034
2decil	166,718	19,425	30,246	28,033	144,332	26,943	23,406	70,485
3decil	117,342	13,201	63,530	12,880	102,647	18,921	15,397	49,610
4decil	122,296	11,302	80,339	10,207	108,430	19,496	16,264	51,705
5decil	137,984	19,269	73,649	10,810	124,152	22,590	19,370	58,337
6decil	153,038	14,844	66,868	9,480	135,512	24,460	21,642	64,702
7decil	209,309	30,269	49,877	10,149	188,824	34,362	32,305	88,492
8decil	256,201	44,247	36,270	11,712	235,666	42,716	42,536	108,317
9decil	288,091	38,212	24,822	10,900	262,472	46,981	49,238	121,800
10decil	374,541	40,110	17,354	7,578	356,341	60,208	74,465	158,349
Weighted sum; bln. CZK	832	110	188	66	752	136	132	352

Figure AIV-2: Expenditures on energies and transport, HBS 2004.

	coal	**gas**	**heat**	**electri-city**	**FUEL**	**MHD**	**BUS**	**RAIL**
1decil	851	5,970	6,634	10,286	8,391	1,233	2,282	570
2decil	869	5,266	7,477	9,490	8,514	1,363	1,398	412
3decil	974	5,301	7,326	8,616	6,483	1,052	1,082	328
4decil	690	5,720	6,650	9,498	7,078	1,247	822	486
5decil	637	6,030	7,260	9,172	7,437	1,210	1,280	505
6decil	1,035	5,115	7,167	8,990	7,422	1,213	1,230	594
7decil	744	5,890	7,298	9,560	8,804	1,552	1,488	718
8decil	883	6,971	7,328	9,942	10,995	1,946	1,413	661
9decil	974	5,999	8,223	9,546	12,022	1,832	1,380	519
10decil	388	5,794	8,831	9,444	11,807	2,590	1,140	605
Weighted sum; bln. CZK	3.38	24.38	31.16	39.71	37.36	6.40	5.68	2.27

Figure AIV-3: Consumption of and paid taxes for energies and fuels, HBS 2004.

	Energy consumption					**Paid taxes**		
	coal (t)	**gas (GJ)**	**heat (GJ)**	**electricity (kWh)**	**motor fuels (l)**	**Excise tax on energies**	**VAT on energies & fuels**	**Tax revenues (sum)**
1decil	0.5	25.1	19.3	3 956.3	321.7	3,748	4,975	8,724
2decil	0.5	22.1	21.8	3 650.2	326.5	3,804	4,671	8,474
3decil	0.6	22.3	21.3	3 314.0	248.6	2,896	4,118	7,014
4decil	0.4	24.0	19.4	3 653.2	271.4	3,162	4,340	7,502
5decil	0.4	25.3	21.1	3 527.8	285.1	3,322	4,484	7,806
6decil	0.6	21.5	20.9	3 457.7	284.6	3,315	4,362	7,677
7decil	0.4	24.7	21.2	3 676.9	337.6	3,933	4,859	8,792
8decil	0.5	29.3	21.3	3 824.0	421.6	4,912	5,514	10,426
9decil	0.6	25.2	23.9	3 671.4	461.0	5,371	5,486	10,857
10decil	0.2	24.3	25.7	3 632.4	452.7	5,274	5,425	10,700
Vážená suma	**2 Mt**	**102 PJ**	**91 PJ**	**15 273 GWh**	**1 433 mil. l**	**16.69**	**20.26**	**36.95**

The Czech tax system: its structure and main changes

The current Czech tax system was established in 1993, when a new tax system reform was introduced. The tax structure has become comparable with those of the EU Member States. Public revenues consist of taxes levied on goods and services, taxes levied on income and property, obligatory social and health insurance contributions, non-tax and capital revenues, and international transfers. The base of the tax system consists of taxes on profits and labour income, value added tax, special excise taxes (mainly on energy, tobaccos and alcohol). The system is supplemented by special taxes (such as road tax, property tax) and special fees including highway-toll. The obligatory social security and health insurance were established in parallel with the tax system. This insurance is paid to particular funds. Payments of the social and health insurance, which is de facto a linear tax on labour income, are shared between employees and employers. The social and health insurance brings a high share of public revenues (about 40%—45% of total public revenues), while the progressive labour income tax has a significantly smaller share: less than 15% of total public revenues). Thus public budgets obtain about 50% of revenues from labour taxation. VAT, taxation on profits and property bring about one third of total public revenues.

The profit tax rate was decreased from 45% before the initial tax reform in 1993 in six steps to the current 28%. Moreover, the tax rate is going to be lowered to 26% in 2005 and to 24% in 2006.

The labour tax was based on six income bands with marginal rates ranging from 15% up to 47%. The social dimension of the labour tax is incorporated through the system of deductibles from the tax base; these deductibles are related mainly to the number and age of children and / or to the number of disabled people in the household. These deductibles are continuously adjusted to the price level. There are currently only four intervals for marginal labour tax rates with 15%, 20%, 25% and 32%; the relevant changes consult with the table.

The most important elements of energy taxation include the VAT and excise taxes. Excise taxes have been applied on certain CH-fuels and oils, tobacco products and alcohol. For the purpose of this paper, we only discuss energy-related taxation. Excise taxes on fuels and oils are levied only on motor fuels, oils, and certain gases[17]. Rates of the excise tax on petrol and diesel were increased in several steps. There is a tax rebate for the excise tax on diesel used in the agriculture sector (so called "green diesel"); 60 per cent of the tax is refunded back to farmers. The excise tax on the light fuel oil for thermal energy generation used to be fully refunded from 1 January 1996; it has only been refunded up to 660 CZK per tonne (21 €) since January 2004 as required by EC Directive 2003/96. The development in relevant rates are summarized in Figure in Appendix. Although excise tax rates on energy nominally increased during the 1990s, the real rates (deflated by CPI) actually fell (Brůha and Ščasný, 2005).

[17] Tax rate on LPG is 125 € per tonne, on CNG it is 106 € per tonne. Gases used for heating purposes are not subject to the taxation.

The VAT with a 23% standard rate[18] and 5% reduced rate was established in 1993. Gasoline, diesel and oils were subject to the standard rate, while other types of energy enjoyed the reduced rate. All remaining energies were moved from the 5% reduced VAT rate to the 22% standard rate in January 1998. The central heating production is an exemption as a transition period for the lower taxation has been applied until the end of 2007. Within the second stage of the Czech Public Finance Reform, the VAT rates changed. The reform implements the relevant EC Directives and includes in particular shifting many goods and services from the 5% reduced rate to the standard VAT rate, and decreasing the standard VAT rate from 22% to 19%.

Figure AIV-4: Labour taxation scheme, Czech Republic, 1993—2005.

	Bands for labour tax thousands CZK, 2000 prices					Rates of labour tax						Deductibles, in CZK, (2000)	
	band 1	band 2	band 3	band 4	band 5	rate 1	rate 2	rate 3	rate 4	rate 5	rate 6	all	child
1993	100	201	301	903	1 806	15%	20%	25%	32%	40%	47%	34 000	15 000
1994	91	182	272	817	1 634	15%	20%	25%	32%	40%	44%	32 678	16 339
1995	83	166	249	748	1 496	15%	20%	25%	32%	40%	43%	33 241	16 620
1996	107	183	260	718		15%	20%	25%	32%	40%		33 631	16 815
1997	99	197	296	887		15%	20%	25%	32%	40%		33 803	16 901
1998	97	194	291	873		15%	20%	25%	32%	40%		34 013	19 108
1999	106	212	324	1 148		15%	20%	25%	32%	40%		36 299	22 453
2000	102	204	312			15%	20%	25%	32%			34 920	21 600
2001	104	209	316			15%	20%	25%	32%			36 332	22 464
2002	102	205	311			15%	20%	25%	32%			35 685	22 064
2003	102	205	310			15%	20%	25%	32%			35 651	23 918
2004	99	199	301			15%	20%	25%	32%			34 582	23 236
2005	98	196	297			15%	20%	25%	32%			34 056	22 883

Figure AIV-5: Excise tax and VAT on energies, Czech Republic 1993—2005.

	Excise taxes					VAT, %			
	CZK, 2000-prices (CPI)		CZK, nomial prices			motor fuels	oils	gas, coal, electricity	Heat
	petrol	diesel	petrol	diesel	oils				
1993	13.71	11.62	8.20	6.95		23%	5%	5%	5%
1994	13.18	10.51	8.71	6.95		23%	23%	5%	5%
1995	12.17	9.74	8.79	7.03	2.00	22%	22%	5%	5%
1996	11.20	8.96	8.79	7.03	7.59	22%	22%	5%	5%
1997	10.32	8.25	8.79	7.03	7.92	22%	22%	5%	5%
1998	10.45	8.65	9.84	8.15	7.92	22%	22%	22%	5%
1999	11.27	8.47	10.84	8.15	8.15	22%	22%	22%	5%
2000	10.84	8.15	10.84	8.15	8.15	22%	22%	22%	5%
2001	10.35	7.78	10.84	8.15	8.15	22%	22%	22%	5%
2002	10.17	7.65	10.84	8.15	8.15	22%	22%	22%	5%
2003	10.16	7.64	10.84	8.15	8.15	22%	22%	22%	5%
2004	10.79	9.07	11.84	9.95	9.95	19%	19%	19%	5%
2005	10.60	8.91	11.84	9.95	9.95	19%	19%	19%	5%

[18] This standard rate was lowered to 22% in 1995 and further to 19% in May 2004.

Environmentally related levies amounted in average about 7% of total public revenues, 8% of tax revenues, or 3% of GDP respectively. They represented 81 bln. CZK (2.7 bln. €), or about 260 € per capita, in the year 2004. Revenues from environmentally-related levies are dominated by revenues from excise tax on motor fuels. Ecological charges – pollution and resource taxes/charges, present only a minor part about 6%. We estimated revenues from VAT applied on energies at about 20 € in 1993—1997, and 50—60 € in 1998—2003 per capita. If we considered these revenues as environmentally-related, their shares would be increased by 1%-point in 1993—1997, and by 2%-points in 1998—2003. Ščasný (2002; 2005) provides a database of bases and revenues from all environmental-related levies being introduced in the Czech Republic during 1993 to 2004. Instances of implicit Environmental Tax Reform appear if a tax burden from factor taxation was shifted towards to higher taxation of energy and environmental use. Such cases are discussed by Brůha and Ščasný (2005), and can be documented by following Figures.

Figure AIV-6: The implicit ETR assessment, the Czech Republic 1993—2004.