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EUROMOD Extension to Indirect Taxation: Final Report

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Editorial Note

This report documents the work done to integrate indirect tax simulation into EUROMOD – the tax-benefit microsimulation model for the European Union – as part of the project "EUROMOD extension to indirect taxation".

The project was conducted jointly by the Department of Economics of the University of Leuven and the Institute for Social and Economic Research (ISER) at the University of Essex and was funded by the European Commission, Joint Research Centre (JRC), Institute for Prospective Technological Studies (IPTS) via Contract No. 198961-2015 A10-UK.

Contract No. 198961-2015 A10-UK

"EUROMOD EXTENSION TO INDIRECT TAXATION"

D3: FINAL REPORT

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APRIL 2017

1. INTRODUCTION

The area of indirect taxes is identified by the European Commission as an important domain for tax policy reforms with potentially wide-ranging socioeconomic effects. There is a renewed interest in tax shifts that reduce labour taxes and increase taxes on commodities, keeping the overall government revenue fixed. While often desirable from an economic or fiscal perspective, these shifts might entail substantial distributional changes. Microsimulation models are particularly suited to investigate how fiscal policy reforms affect different income groups or subgroups of the population.

This report documents the work done to integrate indirect tax simulation into EUROMOD – the tax-benefit microsimulation model for the European Union – as part of the project "EUROMOD extension to indirect taxation". The project delivered an Indirect Tax Tool (ITT) plug-in for EUROMOD that allows the analyst to perform static microsimulation analyses for 10 EU countries in a comparable way on a single platform. The tool allows the evaluation of both the budgetary effects and the equity impact of (simultaneous) reforms to direct and indirect tax policies and to the social benefit system. In order for the tool to work, for the 10 countries covered, consumption expenditures from national Household Budget Survey (HBS) data were used to inform the imputation of expenditure into the existing EUROMOD input data based on the Survey of Income and Living Conditions (SILC). Engel curves were estimated on the aggregated HBS data and the resulting parameter estimates are then used by the ITT in the imputation of expenditures to the EUROMOD input data. Alongside this imputation, indirect tax policy rules have been coded in the country models allowing the tool to produce baseline results for all countries. In a departure from the original proposal to describe and code policy systems up to 2014, systems have been coded for the whole of the period 2011-2016 for all countries.

The project was conducted jointly by the Department of Economics of the University of Leuven and the Institute for Social and Economic Research (ISER) at the University of Essex.

The remainder of this report is organised as follows. In section 2, we provide a brief summary of the project's achievements against the specified tasks, signposting the reader to where she or he might access more detailed information in this report. In section 3, the methodologies for estimating the Engel curves and for the calculation of indirect tax liabilities in the model – including the behavioural assumptions behind those calculations – are described. In section 4, cross-country comparative technical information is provided, including differences in expenditure category definitions, in the scope of simulations, and in the indexation factors used; comparative baseline results are also produced. In section 5, an example policy reform – involving a revenue-neutral switch from direct to indirect tax across all 10 countries – is analysed in terms of its distributional effects. Section 6 offers conclusions across the project as a whole.

2. ACHIEVEMENT AGAINST TASKS

Below we provide an overview of the work done per specified (sub)task.

Main task 1: Country-selection and matching consumption micro-data with EU-SILC

Subtask 1: *Selection of countries*

Belgium, Czech Republic, Greece, Estonia, Latvia, Austria, Poland, Romania, Finland and the United Kingdom were selected as the 10 countries covered by this project – for further details see the **Technical Offer**, **D1: Minutes of the kick-off meeting – summary country selection report**, and **D2: Interim report**.

Reinforcing a message from the interim report, access to national HBS data was not always straightforward and in some cases not possible for 2011 (the year chosen to match the income data for the 2012 SILC on which the chosen EUROMOD input data were based).

Subtask 2: *Description of indirect tax systems*

The indirect tax systems for all countries are documented extensively in the **Country reports (Annexes 2-11)**. In particular, the general characteristics of Value Added Tax (VAT) and excise duties are outlined, as well as their functioning. In each country, a short summary of other indirect taxes is also provided.

In addition, for each country, information needed for the estimation of Engel curves and later simulations has been collected. This information consists of: (1) VAT rates, (2) excises, (3) consumer prices. Aggregate statistics on revenue from VAT and excises have also been documented. The information collected relates to the reporting year of the relevant HBS, as well as information on the policies (and prices) that apply on June 30th for each of 2011 to 2016.

Subtask 3: *Defining relevant variables in household budget surveys*

Treatment of the HBS data – in preparation for its use with EUROMOD input data – followed four steps in each country:

(1) HBS data on 2011 household consumption expenditures (exceptions are: 2012 data for BE, FI, UK; 2009-10 data for AT) were prepared and quality-checked in order to match them to the income reference period of SILC 2012, used as input data for EUROMOD. This is documented in the **Country reports (Annexes 2-11)** and in **Table 6 in the section on Comparative Technical Information (section 4)**.

(2) For 2011-2016, the relevant tax bases or exemption categories were defined and identified per detailed COICOP category. Starting at the lowest commodity level of the HBS - i.e. the most detailed consumption goods - each commodity has been assigned to the respective VAT rate that applies to it and - if applicable - to each excise duty. **See section on Comparative Technical Information (section 4)**.

(3) As HBS data provide spending information at a very detailed commodity level, these have been aggregated (by COICOP category) as estimation of Engel curves can only be performed well for a limited number of commodity groups. In addition to one category for durable spending, and one for non-taxable items, for all countries we have assigned expenditures (COICOP codes) to 15 commodity groups of non-durable spending.

(4) The variables of interest from the HBS have been described and their quality assessed. This has been done by comparing the set of HBS variables with their SILC dataset equivalents. See the **Country reports (Annexes 2-11)**.

Subtask 4: *Estimation of Engel curves*

For each country, and for each of the different commodity groups, Engel curves were estimated on the aggregated HBS data. The resulting parameter estimates serve as input for the regression imputation into the (SILC-based) EUROMOD input data. The work was conducted using standardised Stata do-files, requiring limited country-specific adjustments. A more detailed description of the estimation methodology can be found in **Methodology (Section 3)**.

Subtask 5: *Imputation of expenditures*

Imputation of total expenditures and budget shares to EUROMOD input data, using information on income and household/regional characteristics of the SILC, was undertaken for all countries. Results are presented in the **Country reports (Annexes 2-11)**.

Main task 2: Indirect tax coding in EUROMOD

Subtask 6: *Policy implementation and tax coding*

Indirect tax policy rules have been coded in EUROMOD for 2011-2016 for all countries.

Subtask 7: *External validation*

Macrovalidation consists of producing aggregate EUROMOD results and summary statistics using the input data with imputed expenditures and comparing them with comparable figures from national accounts. Results are presented in the **Country reports (Annexes 2-11)** and cross-country comparisons are made in **Table 11 and Table 12 in the section on Comparative Technical Information (section 4)**.

Subtask 8: *Policy reform analysis*

The policy reform analysis and commentary is presented in **section 5**.

Main task 3: Indirect tax plug-in

Subtask 9: *Development and implementation of a EUROMOD indirect tax plug-in*

A stable Indirect Tax Tool (ITT) plug-in has been produced. The tool can both impute and simulate expenditures. The imputation enriches the standard EUROMOD input data with expenditures, using the previously estimated Engel curves. When simulating, the ITT calculates new expenditures and liabilities based on the user-defined indirect tax policies and according to a set of alternative behavioural assumptions. The tool is able to produce a range of summary statistics on the distributional impact of policy simulations in the same way that EUROMOD provides these statistics for direct tax (and benefit) changes.

A more detailed description of these imputation and simulation functions – and the methodology underpinning them – is provided in the **next section**. A practical user manual is integrated into the tool and is reproduced as **Annex 1**.

3. METHODOLOGY

The process of modelling indirect taxes in EUROMOD consist of three main stages. First, as no (comprehensive) household expenditure information is available in the underlying SILC datasets, we need to imputed expenditures into EUROMOD datasets by the means of parametric expenditure functions (Engel curves), which can be estimated on the basis of household expenditure information from other sources, e.g. Household Budget Survey (HBS). To make the estimation feasible, we employ separate Engel curves for a limited number of aggregate commodity groups: durables and 15 non-durables. The second stage is calculating household indirect tax liabilities on imputed expenditures by aggregate categories. This needs to take into account various types of indirect taxes (VAT, ad valorem excises and specific excises) and that individual commodities within the same aggregate category may be taxed differently. The final stage concerns the simulation of household expenditure and indirect tax liabilities, following a reform in direct and/or indirect tax rules. This section explains all the stages and underlying methodology in detail, building on and extending an earlier methodological note by Decoster and Spiritus (2014).

3.1 Key terminology and notations

3.1.1 Key concepts

ITT	The EUROMOD Indirect Tax Tool to simulate expenditures and indirect taxes
Baseline	Pre-reform system, before changes in direct and/or indirect taxes. Must be specified: - *baseline system: pre-reform direct AND indirect taxes* - *baseline direct taxes: pre-reform direct taxes* - *baseline indirect taxes: pre-reform indirect taxes*
EUROMOD	Refers only to the simulator of direct taxes and cash benefits
Imputation	The process in which the Engel curves are used to impute new expenditures (and savings) into the EUROMOD-output
Simulation	The process of calculating changes in expenditures and quantities as a result of changes in the direct or indirect tax system

3.1.2 Main notation

Generic:

π direct taxes (refers to all direct taxes and cash benefits)
I indexation series

Prices and taxes for individual commodity k :

p_k producer (unit) price

q_k consumer (unit) price

t_k VAT rate (a share of producer price)

a_k specific excise rate (per unit)

v_k ad valorem excise rate (a share of consumer price)

τ_k implicit indirect tax rate

For each household h :

z^h household characteristics
Y^h pre-tax income
y^h disposable income
$\tilde{y}^h$ disposable income with adjusted mean and standard deviation
x_k^h quantity consumed of individual commodity k
e_k^h, e_G^h expenditures on individual commodity k and aggregate commodity G
ω_k^h budget share within aggregate commodity G , $\omega_k^h = e_k^h / e_G^h$
T_k^h, T_G^h tax liability on individual commodity k and aggregate commodity G
d_D^h, d_G^h indicator variable for positive expenditure on durables and aggregate commodity G

D^h expenditures on durables
E^h total non-durable expenditures, $E^h = \sum_G e_G^h$

E_R^h total “remaining” non-durable expenditures, $E_R^h = \sum_{G \in R} e_G^h$

w_G^h share of total non-durable expenditure, $w_G^h \equiv e_G^h / E^h$ and $\sum_G w_G = 1$

r_G^h share of total “residual” non-durable expenditure, $r_G^h \equiv e_G^h / E_R^h$ and $\sum_G r_G = 1$

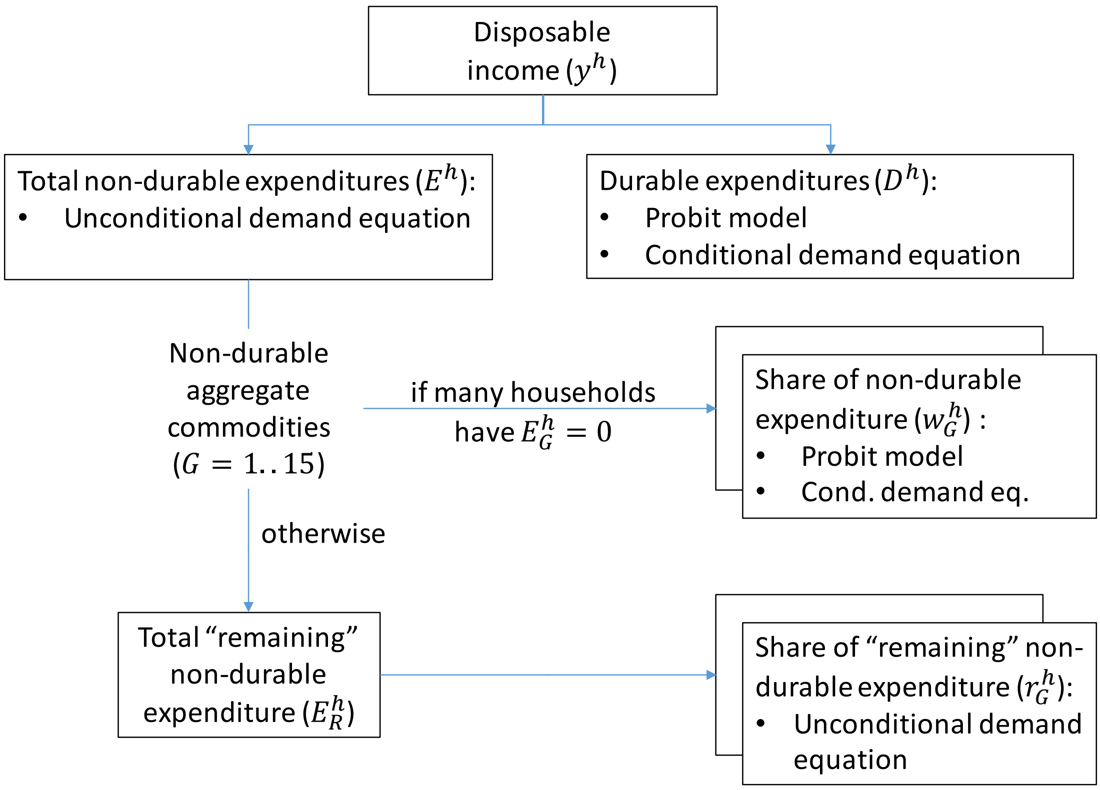
S^h savings, $S^h \equiv y^h - D^h - E^h$.

Symbols without superscript *h* refer to the respective population aggregate instead. Subscripts 0 and 1 are used in addition to denote the baseline situation and reform situation, respectively, when needed. $y(.)$, $E(.)$, $e_G(.)$ and $D(.)$ are functions.

3.2 *Estimation of Engel curves with Household Budget Surveys*

We estimate expenditure functions on the basis of detailed expenditure information in the Household Budget Survey (HBS) in several steps, which are summarised in Figure 1.

Figure 1. The estimation of expenditure functions



We start from total household durable expenditures. Given that a notable share of households may not have purchased durables in the reference period, we estimate first a probit model to determine which households are more likely to have durable expenditures:

$$\Pr\left(d_D^h = 1\right) = \phi\left(\alpha_{D,0} + \sum_m \beta_{D,0}\left(\ln y^h\right)^m + z^h\gamma_{D,0} + \varepsilon_{D,0}^h\right) \tag{2.1}$$

The key explanatory variable is household disposable income in log terms and as an (orthogonal) polynomial of third degree $(m=1,2,3)$ by default, though the final choice is decided on a country-by-country basis depending on the model fit. (Because of log terms, we omit households with very low incomes, $y^h < 1$, from the estimation.) The default set of covariates (z^h) used in the regression includes characteristics of the household head (age polynomials, gender, education levels, activity status), household composition (the number of persons, children and economically active) and other household characteristics (region, ownership of car and computer, tenure type), but the final specification is again country specific.

Conditional on having positive durable expenditures, we then estimate a linear regression model for the amount of durable expenditures with the same set of covariates:

$$\ln D^h = \alpha_D + \sum_m \beta_D \left(\ln y^h\right)^m + z^h \gamma_D + \varepsilon_D^h \quad \text{if} \quad d_D^h = 1 \tag{2.2}$$

A similar model – but unconditional – is estimated for total household expenditures on non-durable goods:

$$\ln E^h = \alpha_E + \sum_m \beta_E \left(\ln y^h\right)^m + z^h \gamma_E + \varepsilon_E^h \tag{2.3}$$

After modelling total household expenditures on durables and non-durables, we carry out similar estimations for detailed expenditures on non-durables as sub-models for (2.3). Given the extensive number of individual commodities typically reported in the HBS, some aggregation of commodities is needed to achieve smooth distributions and feasible estimations: we divide all non-durables commodities into 15 mutually exclusive groups.[1]

Among the non-durable categories, we consider first those where a large proportion of household have zero expenditures – these vary across countries but typical examples include expenditure on alcohol, tobacco, public transport and education. After determining "zero groups" $\left(G \in Z\right)$, a two-step modelling is applied as with durable expenditures. In the first step, a probit model for each such category is set up to estimate the likelihood of having related expenditures:

$$\Pr\left(d_G^h = 1\right) = \phi\left(\alpha_{G,0} + \sum_n \beta_{G,0} \left(\ln E^h\right)^n + z^h \gamma_{G,0} + \varepsilon_{G,0}^h\right) \quad \text{for any } G \in Z \tag{2.4}$$

Instead of household disposable income, we now use total household non-durable expenditure as the main predictor and, conditional on having specific expenditure, estimate the budget share within total household non-durable expenditures, $w_G^h \equiv e_G^h / E^h$:

$$w_G^h = \alpha_G + \sum_n \beta_G \left(\ln E^h\right)^n + z^h \gamma_G + \varepsilon_G^h \quad \text{if} \quad d_G^h = 1 \quad \text{for any } G \in Z \tag{2.5}$$

The specification corresponds to the Engel curve in the Quadratic Almost Ideal Demand System (QUAIDS), without relative price effects.

We are then left with household expenditures on "remaining" non-durable categories $\left(G \in R\right)$, their sum corresponding to:

[1] Groups are as follows and the same for all countries: (1) food and non-alcoholic beverages; (2) alcoholic beverages; (3) tobacco; (4) clothing and footwear; (5) home fuels, electricity and water; (6) housing and rents; (7) household goods and services; (8) health; (9) private transport; (10) public transport; (11) communication; (12) recreation and culture; (13) education; (14) restaurants and hotels; (15) other goods and services.

$$E_R^h = E^h\left(1 - \sum_{G \in Z} w_G\right) \tag{2.6}$$

For those, we estimate the budget share within total household remaining non-durable expenditures, $r_G^h \equiv e_G^h / E_R^h$:

$$r_G^h = \alpha_G + \sum_n \beta_G \left(\ln E_R^h\right)^n + z^h \gamma_G + \varepsilon_G^h \quad \text{for any } G \in R \tag{2.7}$$

Log total non-durable expenditure $\left(\ln E^h\right)$ and log total remaining non-durable expenditure $\left(\ln E_R^h\right)$ are included as (orthogonal) polynomials of second degree $(n = 1,2)$ by default.

This concludes our system of expenditure functions and we can define savings as a residual of income less total expenditure

$$S^h \equiv y^h - D^h - E^h \tag{2.8}$$

which can take either positive or negative values.

3.3 Imputation of expenditures into EUROMOD

In the next step, we use expenditure functions estimated on the HBS data to impute expenditures into EUROMOD datasets for each household on the basis of their baseline disposable income y_0^h and using the same set of covariates z^h .

There are two further aspects, which need special attention:

- First, the HBS reference year of expenditure (budget) information and the EUROMOD income reference year may not be the same. When this is the case, we first scale EUROMOD (raw) disposable incomes y_{EM}^h to match the HBS reference year using an index series I , before imputing expenditures:

$$y^h = y_{EM}^h \frac{I_e}{I_y} \tag{3.1}$$

  where I_e and I_y refer to the value of index in the expenditure and income reference year, respectively. Our preferred option is to apply indexation in line with nominal growth in total private consumption (from national accounts) to ensure that total imputed expenditure match the external aggregates as closely as possible. Alternatively, one could consider using nominal GDP or a general price index. (ITT is flexible and can work with multiple series of indices.) After using scaled incomes to impute expenditures and savings, we reverse the adjustment and return to the nominal levels of the income reference year by scaling expenditures and savings with I_y / I_e .

- Second, even when the reference year for incomes and expenditures are the same, the distribution of incomes may substantially differ between the HBS and the EUROMOD dataset. We therefore align the income distribution in the EUROMOD dataset to match the mean and variance in the HBS and use the adjusted distribution to impute total durable and non-durable expenditure:

$$\tilde{y}^h = \frac{y^h - \bar{y}}{\sigma_y} \sigma_{y,HBS} + \bar{y}_{HBS} \tag{3.2}$$

where $\bar{y}$ and σ_y refer to the mean and standard deviation of disposable incomes. Mean and standard deviation for the HBS and EUROMOD variables are calculated without extreme positive values, which are determined using the Chauvenet's criterion and assuming lognormal distribution:

$$\frac{\ln y - \overline{\ln y}}{\sigma_{\ln y}} > Z_{1-(2N)^{-1}} \tag{3.3}$$

where N_h denotes the number of households in the sample. (As in the estimation stage, households with very low incomes, $y^h < 1$, are excluded altogether.)
In the same way, we align the distribution of imputed total non-durables and total "remaining" non-durables before using them as covariates to impute the budget share of each aggregate commodity. It is important to emphasise that aligned distributions are <u>only</u> used for predictions and not as core variables in the model.

Note that both types of adjustment are only needed for baseline imputations of expenditures, while reform simulations apply specific behavioural assumptions (constant quantities vs constant budget shares) in turn to baseline expenditures.

A further technical note concerns the transformation of imputed log values into levels. As

$$E\left[\exp\left(\alpha + ... + z^h\gamma + \varepsilon^h\right)\right] = \exp\left(\alpha + ... + z^h\gamma\right) E\left[\exp\left(\varepsilon^h\right)\right] \tag{3.4}$$

it is not sufficient to take simply anti-logs of imputed expenditure. Assuming that ε^h are i.i.d., we can consistently estimate $E\left[\exp\left(\varepsilon^h\right)\right]$ as $N_h^{-1}\sum_h \exp\left(\hat{\varepsilon}_{HBS}^h\right)$ and use this for transforming imputed log durables and log non-durables into monetary amounts.[2]

In summary, for each household h, ITT will then:

1. Scale disposable income to match the expenditure reference year: $y^h = y_{EM}^h \left(I_e / I_y\right)$.

[2] See Cameron and Trivedi (2010, p. 108).

2. Impute durable expenditures using (adjusted) disposable income and household characteristics: $\ln D^h = D\left(\tilde{y}^h, \mathrm{z}^h\right)$.
3. Impute total non-durable expenditures using (adjusted) disposable income and household characteristics: $\ln E^h = E\left(\tilde{y}^h, \mathrm{z}^h\right)$.
4. Compute savings S^h as a residual: $S^h = y^h - E^h - D^h$.
5. Impute non-durable expenditure shares. First, $w_G^h = w\left(\tilde{E}^h, \mathrm{z}^h\right)$ for $G \in Z$ ("zero groups"), using (adjusted) total non-durable expenditures and household characteristics. Second, $r_G^h = w\left(\tilde{E}_R^h, \mathrm{z}^h\right)$ for $G \in R$ ("remaining groups"), using (adjusted) total "remaining" non-durable expenditures and household characteristics.
6. Calculate expenditures on each of the non-durable categories: $e_G^h = w_G^h E^h$ for $G \in Z$ and $r_G^h = w_G^h E_R^h$ for $G \in R$.
7. Finally, scale income, expenditures and savings with I_y / I_e to match the income reference year.

Table 1 lists the outcomes of the imputation.

Table 1: Household-level output of the baseline imputation

Disposable income:		$y_0^h = y\left(Y_0^h, \pi_0, \mathrm{z}^h\right)$
Durables:	Expenditures	$D_0^h = D\left(y_0^h, \mathrm{z}^h\right)$
Non-durable commodities:	Total expenditures	$E_0^h = E\left(y_0^h, \mathrm{z}^h\right)$
	Expenditures of "zero groups"	$e_{G,0}^h = w_G\left(E_0^h, \mathrm{z}^h\right) E_0^h$ for any $G \in Z$
	Expenditures of remaining groups	$e_{G,0}^h = r_G\left(E_{R,0}^h, \mathrm{z}^h\right) E_{R,0}^h$ for any $G \in R$
Savings:		$S_0^h = y_0^h - E_0^h - D_0^h$

3.4 Calculation of implicit tax rates and indirect tax liabilities on individual commodities

3.4.1 Implicit tax rates

We start from the relationship between consumer price q_k and producer price p_k for individual commodity k:

$$q_k = \left(1 + t_k\right)\left(p_k + a_k + \nu_k q_k\right) \tag{4.1}$$

where the consumer price appears on both sides. Producer prices are generally not observed but can be calculated from consumer prices and indirect tax parameters by rearranging (4.1):

$$p_k = q_k\left(\frac{1}{1+t_k} - v_k\right) - a_k \tag{4.2}$$

Equation (4.2) is used in ITT to check the consistency of baseline indirect tax parameters, i.e. $p_k > 0$. Let us next define implicit tax rate τ_k on commodity k (relative to producer prices):

$$q_k \equiv (1+\tau_k)\,\mathrm{p}_k \tag{4.3}$$

Inserting (4.3) into (4.2) and rearranging, the implicit tax rate can be expressed as (using (4.2) for producer prices):

$$\tau_k = \frac{(1+t_k)(1+a_k/p_k)}{1-(1+t_k)v_k} - 1 \tag{4.4}$$

Furthermore, the implicit tax rate (relative to expenditure in consumer prices) can be decomposed to show the contribution of VAT rate, specific excise and ad valorem excise. For this, substitute p_k in (4.1) using (4.3) and divide both sides with q_k to get

$$\frac{1}{1+t_k} = \frac{1}{1+\tau_k} + \frac{a_k}{q_k} + v_k \tag{4.5}$$

Finally, adding $\frac{t_k\tau_k - 1}{(1+t_k)(1+\tau_k)}$ to both sides of (4.5) and rearranging, we obtain:

$$\frac{\tau_k}{1+\tau_k} = \frac{t_k}{1+t_k} + \frac{a_k}{q_k} + v_k \tag{4.6}$$

3.4.2 Household expenditures and indirect tax liabilities

Expenditures and indirect tax liability on commodity k depend on indirect tax parameters and household consumption. Expenditures on commodity k by household h are

$$e_k^h = q_k x_k^h = (1+\tau_k)\, p_k x_k^h \tag{4.7}$$

Household’s total indirect tax liability and its components – VAT, ad valorem excises and specific excises – are defined as follows:

$$T_k^h \equiv \tau_k p_k x_k^h = \frac{\tau_k}{1+\tau_k} e_k^h$$
$$T_k^{h,t} \equiv \frac{t_k}{1+t_k} e_k^h$$
$$T_k^{h,v} \equiv v_k e_k^h$$
$$T_k^{h,a} \equiv a_k x_k^h = \frac{a_k}{q_k} e_k^h$$
(4.8)

Importantly, these expressions allow calculating indirect tax liabilities from *observed* expenditures and consumer prices. Using (4.6) it is straightforward to show that $T_k^h = T_k^{h,t} + T_k^{h,v} + T_k^{h,a}$.

Total tax revenues on commodity k can be calculated by summing tax liabilities across households: as implicit tax rates on individual commodities are identical for all households, corresponding expressions are obtained by replacing e_k^h with $e_k = \sum_h e_k^h$ in (4.8).

3.5 Calculation of baseline implicit tax rate and indirect tax liabilities on aggregate commodities in EUROMOD

Tax liabilities on individual commodities can only be calculated with detailed expenditure information available in the Household Budget Survey (HBS), while in EUROMOD we simulate expenditures (in consumer prices) on aggregate commodities. We therefore need to derive expressions for implicit tax rates and tax liabilities on aggregate commodities. As will be evident, we also need to utilise detailed expenditure information in the HBS to achieve that.

3.5.1 Implicit tax rates

We define implicit tax rate τ_G on aggregate commodity *G* using the following identity (in analogue to τ_k), which links population-level tax liabilities and expenditures:

$$T_G \equiv \frac{\tau_G}{1+\tau_G} e_G \quad (5.1)$$

Noting that population totals by aggregate commodities equal the sum of respective terms over individual commodities belonging to the category in question, $e_G \equiv \sum_{k\in G} e_k$ and $T_G \equiv \sum_{k\in G} T_k$, we rearrange (5.1) to express τ_G in terms of quantities obtained earlier:

$$\tau_G = \frac{T_G}{e_G - T_G} = \frac{\sum_{k\in G} T_k}{\sum_{k\in G}(e_k - T_k)} = \frac{\sum_{k\in G} e_k \tau_k / (1+\tau_k)}{\sum_{k\in G} e_k \left[1 - \tau_k / (1+\tau_k)\right]} = \frac{\sum_{k\in G} e_k \tau_k / (1+\tau_k)}{\sum_{k\in G} e_k / (1+\tau_k)}$$
(5.2)

In the baseline scenario, implicit tax rates for aggregate commodities are calculated on the basis of (5.2) in ITT, in combination with (4.4) to derive implicit tax rates on individual commodities τ_k and utilising total expenditure on individual commodities $e_{k,HBS}$ from the HBS. Using (4.7), equation (5.2) can also be expressed as

$$\tau_G = \sum_{k \in G} \tau_k \frac{p_k x_k}{\sum_{k \in G} p_k x_k} \tag{5.3}$$

demonstrating that the implicit tax rate on aggregate commodity *G* is a weighted sum of implicit tax rates on individual commodities in this category, using the budget share of individual commodities in producer prices as weights.

3.5.2 Household indirect tax liabilities

To calculate household indirect tax liabilities and its components (VAT, ad valorem excises and specific excises) from household expenditures on aggregate commodities (in consumer prices), we need to know the budget shares of individual commodities within aggregate categories for each household but this information is not available with our modelling approach in EUROMOD. As an approximation, we use population-level shares observed in the HBS and assume that these apply to all households (**GA.0**):

$$\frac{e_k^h}{e_G^h} = \frac{e_{k,HBS}}{e_{G,HBS}} \equiv \omega_{k,HBS} \quad \text{for any k} \in G \tag{5.4}$$

We can then proceed with calculating household total indirect tax liabilities on aggregate commodities and by tax components, building on equations (5.4) and (4.8):

$$\begin{aligned}
T_G^h &= \sum_{k \in G} \frac{\tau_k}{1+\tau_k} e_k^h = e_G^h \sum_{k \in G} \frac{\tau_k}{1+\tau_k} \omega_{k,HBS} \\
T_G^{h,t} &= \sum_{k \in G} \frac{t_k}{1+t_k} e_k^h = e_G^h \sum_{k \in G} \frac{t_k}{1+t_k} \omega_{k,HBS} \\
T_G^{h,v} &= \sum_{k \in G} v_k e_k^h = e_G^h \sum_{k \in G} v_k \omega_{k,HBS} \\
T_G^{h,a} &= \sum_{k \in G} \frac{a_k}{q_k} e_k^h = e_G^h \sum_{k \in G} \frac{a_k}{q_k} \omega_{k,HBS}
\end{aligned} \tag{5.5}$$

Using equation (4.6), it is again straightforward to check that $T_G^h = T_G^{h,t} + T_G^{h,v} + T_G^{h,a}$. Furthermore, as $T_G = \sum_h T_G^h$, we can link (5.1) and the first equation of (5.5) from which it follows (note that the second summation term is not household specific and can be brought outside the first summation term):

$$\frac{\tau_G}{1+\tau_G}e_G = \sum_h e_G^h \sum_{k\in G}\frac{\tau_k}{1+\tau_k}\omega_{k,HBS} \Rightarrow \frac{\tau_G}{1+\tau_G} = \sum_{k\in G}\frac{\tau_k}{1+\tau_k}\omega_{k,HBS} \tag{5.6}$$

Hence, total indirect tax liability of household h, can also be expressed in terms of the implicit tax rate on aggregate commodity:

$$T_G^h = \frac{\tau_G}{1+\tau_G}e_G^h \tag{5.7}$$

3.6 Simulation of reforms in direct and indirect taxes in EUROMOD

We explain next how EUROMOD and ITT deal with reforms in direct taxes (changes in π) and indirect taxes (changes in τ), i.e. going from (π_0, τ_0) to (π_1, τ_1). In the simulation phase, new expenditures and indirect tax liabilities are derived from changes in disposable incomes and/or indirect tax parameters, under certain assumptions, which are explained here. For this phase, the data already need to include imputed expenditures in the baseline.

3.6.1 Implicit tax rates on individual and aggregate commodities

First, we make two general assumptions when simulating indirect taxes in reform scenarios, constant labour supply (**GA.1**) and constant producer prices (**GA.2**):

$$\begin{aligned} Y_0^h &= Y_1^h \\ p_{k,0} &= p_{k,1} \end{aligned} \tag{6.1}$$

The first assumption indicates that peoples' pre-tax incomes remain unchanged and any changes in disposable incomes are only due to changes in direct taxes and cash benefits (π). The second assumption implies that indirect tax changes are fully passed through to the consumers and allows us to derive new implicit tax rates on individual commodities $\tau_{k,1}$ from (4.4):

$$\tau_{k,1} = \frac{(1+t_{k,1})(1+a_{k,1}/p_{k,0})}{1-(1+t_{k,1})v_{k,1}} - 1 \tag{6.2}$$

To calculate new implicit tax rates on aggregate commodities $\tau_{G,1}$ and household indirect tax liabilities, we make a third general assumption (**GA.3**) similar to (5.4), that the share of household reform expenditure on each individual commodity in the same aggregate category equals the population share observed in the HBS:

$$\frac{e_{k,1}^h}{e_{G,1}^h} = \frac{e_{k,HBS}}{e_{G,HBS}} = \omega_{k,HBS} \quad \text{for any } k \in G \tag{6.3}$$

Note that in combination with (5.4) this implies that the budget shares of *individual* commodities are assumed to remain constant in the reform scenario. Equation (6.3) further implies that the budget share also remains constant at the population level $e_{k,1}/e_{G,1} = \omega_{k,HBS}$, which is a weaker assumption and sufficient to derive $\tau_{G,1}$. Nevertheless, we impose GA.3 at the household level as this will be later needed to derive household indirect taxes. Using (6.3) , we can rewrite (5.2) for the reform scenario:

$$\tau_{G,1} = \frac{\sum_{k\in G} e_{k,1}\tau_{k,1}/(1+\tau_{k,1})}{\sum_{k\in G} e_{k,1}/(1+\tau_{k,1})} = \frac{\sum_{k\in G} e_{k,HBS}\tau_{k,1}/(1+\tau_{k,1})}{\sum_{k\in G} e_{k,HBS}/(1+\tau_{k,1})} \qquad (6.4)$$

Two additional general assumptions were employed in the earlier version of ITT: constant nominal savings (except in the constant quantities scenario) and constant quantities of durables (except in the constant shares scenario). These have been discarded as the two main behavioural scenarios – constant quantities and constant expenditure shares – were extended to both non-durable and durable commodities. We will discuss next how new household expenditures can be obtained under either behavioural assumption and, in the final step, calculate new household indirect tax liabilities.

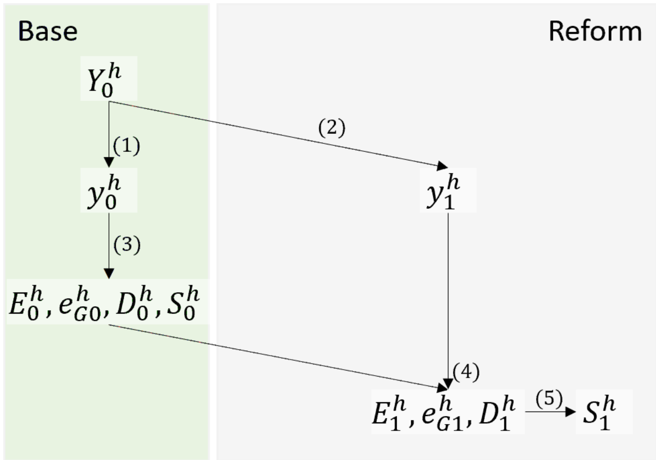
3.6.2 Household expenditures: constant quantities

Previously, we had the possibility of, on top of the general assumption of fixed durable consumption, also to keep the quantities of non-durable commodities fixed. However, when formulating this assumption, we had in mind that it would *only* apply to the indirect tax part of the analysis. That means, that, in the previous version of ITT, when disposable income changed as well, we in fact determined new expenditures twice, causing a lot of confusion.

We have revised ITT, extending the behavioural assumption of “constant quantities” to the whole change triggered by the reform, i.e. both the income change and the price change. The implications of this choice are shown in the table below. We remove the “re-imputation” of expenditures and calculate new expenditures on both durables and non-durables, based on the constant quantities assumption and the new consumer prices. Savings are determined as the residual between the new total expenditures and the new disposable income, and cannot be kept constant of course.

This ought to make the simulation much more transparent. Note that, when there is no indirect tax change, then under the behavioural assumption of fixed quantities, the entire change in disposable income is channelled into a change of savings. In fact, for welfare analysis, one can then limit oneself to changes in disposable income.

Table 2: Revised implementation of the assumption of fixed quantities



(1)	EUROMOD simulates baseline disposable income y_0^h using baseline direct taxes π_0.
(2)	EUROMOD simulates reform disposable income y_1^h using reform direct taxes π_1.
(3)	ITT imputes the baseline expenditures D_0^h, E_0^h, $e_{G,0}^h$ on the baseline disposable income y_0^h. Savings are determined as the residual $S_0^h = y_0^h - E_0^h - D_0^h$.
(4)	ITT simulates a change in the indirect tax system, and computes new expenditures, given constant quantities, $x_{D,1}^h = x_{D,0}^h$ and $x_{G,1}^h = x_{G,0}^h$, the change in indirect taxes will translate in new expenditures on durables and non-durables D_1^h, E_1^h, $e_{G,1}^h$.
(5)	ITT computes the savings S_1^h as a residual using the new expenditures on durables and non-durables D_1^h, E_1^h, $e_{G,1}^h$, and the disposable income in the reform scenario y_1^h.

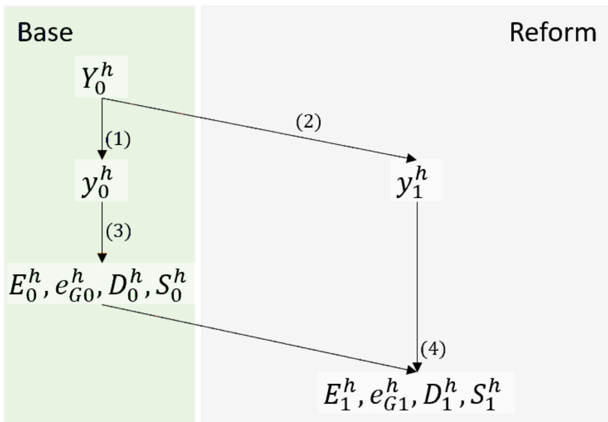
Table 3: Output of joint direct and indirect tax simulation under constant quantities

		Reform
Disposable income:		$y_1^h = y\left(Y_0^h, \pi_1, z^h\right)$
Durables:	Expenditures	$D_1^h = \frac{D\left(y_0^h, z^h\right)}{1+\tau_{D,0}}\left(1+\tau_{D,1}\right)$
Non-durable commodities:	Total expenditures	$E_1^h = \sum e_{G,1}^h$
	Expenditures on aggregate commodities	$e_{G,1}^h = \frac{e_G\left(E_0^h, z^h\right)}{1+\tau_{G,0}}\left(1+\tau_{G,1}\right)$
Savings:		$S_1^h = y_1^h - E_1^h - D_1^h$

3.6.3 Household expenditures: constant expenditure shares

The *fixed expenditure shares* assumption implies that expenditures for each nondurable commodity are adjusted such that each expenditure share $w_{G,0}^h \equiv \frac{e_{G,0}^h}{E_0^h}$ is constant in the reform: $w_{G,0}^h = w_{G,1}^h$. Previously, the same problem as with the assumption of fixed quantities arose as assumptions made at different steps were inconsistent and confusing. We therefore further revised the ITT, also extending the assumption of "constant shares" throughout the whole simulation. So, both savings, expenditures on durables, and expenditures on non-durables are all determined on the basis of the assumption that the income shares are the ones obtained in the baseline. In the revised version, the savings *rate* is kept constant, instead of nominal savings as in the previous version.

Table 4: Revised implementation of the assumption of fixed shares



(1)	EUROMOD simulates baseline disposable income y_0^h using baseline direct taxes π_0.
(2)	EUROMOD simulates reform disposable income y_1^h using reform direct taxes π_1.
(3)	ITT imputes the baseline expenditures D_0^h, E_0^h, $e_{G,0}^h$ on the baseline disposable income y_0^h. It follows that savings in the baseline are the residual $S_0^h = y_0^h - E_0^h - D_0^h$.
(4)	ITT simulates the expenditures for the reform disposable incomes y_1^h, using the income shares from the baseline imputation in (3): $D_1^h = \frac{D_0^h}{y_0^h} y_1^h$, $E_1^h = \frac{E_0^h}{y_0^h} y_1^h$, $S_1^h = \frac{S_0^h}{y_0^h} y_1^h$ and $e_{G,1}^h = \frac{e_{G,0}^h}{y_0^h} y_1^h$

Table 5: Output of joint direct and indirect tax simulation under constant shares

		Reform
Disposable income:		$y_1^h = y\left(Y_0^h, \pi_1, z^h\right)$
Durables:	Expenditures	$D_1^h = \frac{D_0^h}{y_0^h} y_1^h$
Non-durable commodities:	Total expenditures	$E_1^h = \frac{E_0^h}{y_0^h} y_1^h$
	Expenditures on aggregate commodities	$e_{G,1}^h = \frac{e_{G,0}^h}{y_0^h} y_1^h$
Savings:		$S_1^h = \frac{S_0^h}{y_0^h} y_1^h$

3.6.4 Household indirect tax liabilities

Having obtained new household expenditures on aggregate commodities, $e_{G,1}^h$, on the basis of either of the two behavioural assumptions, we can calculate household indirect tax liabilities and its components in analogue to (5.5) using the assumption (6.3):

$$
\begin{aligned}
T_{G,1}^{h} &= \sum_{k\in G} \frac{\tau_{k,1}}{1+\tau_{k,1}} e_{k,1}^h = e_{G,1}^h \sum_{k\in G} \frac{\tau_{k,1}}{1+\tau_{k,1}} \omega_{k,HBS} \\
T_{G,1}^{h,t} &= \sum_{k\in G} \frac{t_{k,1}}{1+t_{k,1}} e_{k,1}^h = e_{G,1}^h \sum_{k\in G} \frac{t_{k,1}}{1+t_{k,1}} \omega_{k,HBS} \\
T_{G,1}^{h,v} &= \sum_{k\in G} v_{k,1} e_{k,1}^h = e_{G,1}^h \sum_{k\in G} v_{k,1} \omega_{k,HBS} \\
T_{G,1}^{h,a} &= \sum_{k\in G} \frac{a_{k,1}}{q_{k,1}} e_{k,1}^h = e_{G,1}^h \sum_{k\in G} \frac{a_{k,1}}{q_{k,1}} \omega_{k,HBS} = e_{G,1}^h \sum_{k\in G} \frac{1+\tau_{k,0}}{1+\tau_{k,1}} \frac{a_{k,1}}{q_{k,0}} \omega_{k,HBS}
\end{aligned}
\tag{6.5}
$$

Note that the last expression for specific excises is rearranged to replace (unknown) consumer prices after the reform with known quantities, relying on our assumption of constant producer prices (GA.2) and equation (4.3).

3.7 Evaluation and welfare analysis

Changes in indirect taxes affect consumer prices, and hence real disposable income of households. This comes on top of possible changes in nominal income as simulated by the standard tax benefit simulations of EUROMOD. In this subsection, we explain how to integrate the price change and the nominal income change into a money metric of change in household welfare.

A money metric of change in welfare is defined as the difference in minimal expenditures at a set of reference consumer prices $\mathbf{q}$ to reach the utility pre– and post–reform, say V_0^h and V_1^h. The minimal level of expenditures needed to obtain a welfare level $\overline{V}$ at given prices $\mathbf{q}$ is expressed by the expenditure function, $E\left(\mathbf{q},\overline{V}\right)$. So, a money metric of the change of welfare is defined as:

$$\Delta W^h = E\left(\mathbf{q},V_1^h\right) - E\left(\mathbf{q},V_0^h\right). \tag{7.1}$$

We will now establish a connection between this measure and the compensating and equivalent variation, and show how these can be approximated by changes in direct and indirect taxes paid under some of the behavioural assumptions spelled out above.

3.7.1 Using the compensating variation

Let $V(\mathbf{q},y)$ be the indirect utility function (of income and prices). The compensating variation (CV^h) is then implicitly defined by:

$$V\left(\mathbf{q_1},y_1^h + CV^h\right) = V\left(\mathbf{q_0},y_0^h\right). \tag{7.2}$$

The compensating variation is the monetary compensation a household should receive in the post-reform situation, that is under the new prices $\mathbf{q}_1$, and given the new income y_1^h, in order to be equally well off as before the reform, that is under the old prices $\mathbf{q}_0$, and given the old income y_0^h. Note that the value CV^h defined in equation (7.2) takes up the welfare effect of both the price change, and the change in disposable income. Below we will show how we can disentangle both effects and write CV^h as the sum of a so-called "pure" price change (keeping disposable income fixed at some given value), and a change in disposable income at a given price vector.

To interpret the sign of CV^h, and link it to the sign of ΔW^h, note that in case of a pure price increase (and hence the same income as before), the household needs to be compensated with an income *increase*, and CV^h will be positive. The sign of ΔW^h being opposite to the one of CV^h, is negative in this case. In case of a pure change in disposable income, that is keeping prices fixed at the pre-reform situation, the sign of ΔW^h should equal that of the change in disposable income. As will be shown below, this will indeed be the case.

We can solve for the value of CV^h in equation (7.2), by inverting the V-function at the LHS around its second argument. The inverse of the indirect utility function is known to be equal to the expenditure function introduced earlier as $E\left(\mathbf{q},\overline{V}\right)$. Inverting V yields the second argument of the LHS of equation (7.2), as a function of the price vector $\mathbf{q_1}$ and the value at the RHS of equation (7.2):

$$\mathrm{y}_1^{\mathrm{h}} + \mathrm{CV}^{\mathrm{h}} = E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, \mathrm{y}_0^{\mathrm{h}}\right)\right), \tag{7.3}$$

And hence:

$$\begin{aligned} \mathrm{CV}^{\mathrm{h}} &= E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, \mathrm{y}_0^{\mathrm{h}}\right)\right) - \mathrm{y}_1^{\mathrm{h}} \\ &= E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, \mathrm{y}_0^{\mathrm{h}}\right)\right) - E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, \mathrm{y}_1^{\mathrm{h}}\right)\right) \\ &= E\left(\mathbf{q}_1, \mathrm{V}_0^{\mathrm{h}}\right) \qquad\quad - E\left(\mathbf{q}_1, \mathrm{V}_1^{\mathrm{h}}\right), \end{aligned} \tag{7.4}$$

where in the second line we have used the fact that $\mathrm{y}_1^{\mathrm{h}} \equiv E\left(\mathbf{q}_1, \mathrm{V}\left(\mathbf{q}_1, \mathrm{y}_1^{\mathrm{h}}\right)\right)$. The third line of equation (7.4) clearly shows how CV^{h} is a money metric of the welfare change (i.e. comparing $\mathrm{V}_0^{\mathrm{h}}$ with $\mathrm{V}_1^{\mathrm{h}}$) of a price and income change, using the post-reform prices $\mathbf{q}_1$ as reference prices in the money metric. Comparing the third line of (7.4) with how we defined the welfare change $\Delta\mathrm{W}^{\mathrm{h}}$ in (7.1) shows that:

$$\Delta\mathrm{W}_{CV}^{h} = -\mathrm{CV}^{\mathrm{h}}, \tag{7.5}$$

where we have now added a subscript to the welfare change to denote that it is obtained from the definition of the compensating variation.

Note that the fixing of the reference price vector, in this case at the post-reform prices $\mathbf{q}_1$, does not remove pre-reform prices $\mathbf{q}_0$ as an argument of the welfare change. Indeed, the second line of equation (7.4) makes clear that with changes in both prices and incomes, the value CV^{h} depends on all four arguments: $\mathbf{q}_0$, $\mathbf{q}_1$, y_0^{h} and y_1^{h}. For further reference, we therefore summarize the second line of equation (7.4) as:

$$\mathrm{CV}^{\mathrm{h}} = E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, \mathrm{y}_0^{\mathrm{h}}\right)\right) - E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, \mathrm{y}_1^{\mathrm{h}}\right)\right) = CV\left(\mathbf{q}_0, \mathbf{q}_1, \mathrm{y}_0^{\mathrm{h}}, \mathrm{y}_1^{\mathrm{h}}\right). \tag{7.6}$$

To decompose the welfare change $\Delta\mathrm{W}_{CV}^{h}$ in the effect of the change in disposable income, and the "pure" change in prices, we will make use of a specific form of equation (7.6), i.e. the one in which we keep disposable income unchanged, i.e. in which $\mathrm{y}_1^{h} = \mathrm{y}_0^{h}$, and which we hence will denote by y_0^{h}. In that case, equation (7.6) reads as:

$$CV\left(\mathbf{q}_0, \mathbf{q}_1, \mathrm{y}_0^{\mathrm{h}}, \mathrm{y}_0^{\mathrm{h}}\right) = E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, \mathrm{y}_0^{\mathrm{h}}\right)\right) - E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, \mathrm{y}_0^{\mathrm{h}}\right)\right). \tag{7.7}$$

Since $y_0^h = E\left(\mathbf{q}, V\left(\mathbf{q}, y_0^h\right)\right)$ holds for any price vector $\mathbf{q}$, we can also write the second term in equation (7.7) with the pre reform price vector $\mathbf{q}_0$ [3]:

$$CV\left(\mathbf{q}_0, \mathbf{q}_1, y_0^h, y_0^h\right) = E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, y_0^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_0, y_0^h\right)\right). \tag{7.8}$$

This equation clearly shows how the compensating variation keeping income fixed (in the present case at level y_0^h), evaluates the pure price change from $\mathbf{q}_0$ to $\mathbf{q}_1$ by comparing the expenditure function for the two price vectors, evaluated at the pre-reform utility level $V_0^h = V\left(\mathbf{q}_0, y_0^h\right)$.

We now use (7.8) to decompose the welfare change ΔW_{CV}^h of equation (7.5) into the change of disposable income, and the welfare effect of a pure price change. Using equation (7.4), ΔW_{CV}^h can be written:

$$\Delta W_{CV}^h = y_1^h - E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, y_0^h\right)\right). \tag{7.9}$$

Adding and subtracting y_0^h yields:

$$\Delta W_{CV}^h = \left[y_1^h - y_0^h\right] - \left[E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, y_0^h\right)\right) - y_0^h\right]. \tag{7.10}$$

Given that $y_0^h = E\left(\mathbf{q}, V\left(\mathbf{q}, y_0^h\right)\right)$, equation (7.10) can also be written as:

$$\Delta W_{CV}^h = \left[y_1^h - y_0^h\right] - \left[E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, y_0^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_0, y_0^h\right)\right)\right]. \tag{7.11}$$

The welfare effect ΔW_{CV}^h is the sum of the change in disposable income in the first square brackets, and a "pure" price effect in the second square brackets. This "pure" price effect is equal to $CV\left(\mathbf{q}_0, \mathbf{q}_1, y_0^h, y_0^h\right)$ as defined in equation (7.8), i.e. the compensating variation, evaluated in the pre-reform disposable income y_0^h:

$$\Delta W_{CV}^h = \left[y_1^h - y_0^h\right] - CV\left(\mathbf{q}_0, \mathbf{q}_1, y_0^h, y_0^h\right). \tag{7.12}$$

We do not dispose of an expenditure function to calculate the price term in equation (7.12). In this final step, we show how we rely on a standard approximation used in the literature. It is based on replacing $E\left(\mathbf{q}_1, V\left(\mathbf{q}_0, y_0^h\right)\right)$ in the price term of

[3] Note that equation (7.8) is in fact the definition of the compensating variation appearing in many (if not most) textbooks, i.e. with income unchanged.

$$\Delta W_{CV}^{h}=\left[y_{1}^{h}-y_{0}^{h}\right]-\left[E\left(\mathbf{q}_{1},V\left(\mathbf{q}_{0},y_{0}^{h}\right)\right)-E\left(\mathbf{q}_{0},V\left(\mathbf{q}_{0},y_{0}^{h}\right)\right)\right], \tag{7.13}$$

with the expenditures needed to buy the pre-reform quantities $\mathbf{x_0^h}$ at the new prices $\mathbf{q}_1$. We know that the pre-reform quantities $\mathbf{x_0^h}$ were utility maximizing, and hence cost minimizing, at the pre-reform prices $\mathbf{q}_0$. But this pre-reform bundle is not necessarily the cost-minimizing bundle at the new prices $\mathbf{q}_1$. Therefore, we have:

$$E\left(\mathbf{q}_{1},V\left(\mathbf{q}_{0},y_{0}^{h}\right)\right)\leq\mathbf{q}_{1}'x_{0}^{h}. \tag{7.14}$$

If we replace $E\left(\mathbf{q}_{1},V\left(\mathbf{q}_{0},y_{0}^{h}\right)\right)$ in equation (7.13) with the number $\mathbf{q}_{1}'x_{0}^{h}$, which is possibly higher, the effect of the price change in equation (7.13) is possibly overestimated (i.e. the number we subtract as the second square bracket is too large). Therefore, this approximation through the RHS of equation (7.14) yields a lower bound of the exact welfare change ΔW_{CV}^{h}:

$$\Delta W_{CV}^{h}\geq\left[y_{1}^{h}-y_{0}^{h}\right]-\left[\mathbf{q}_{1}'x_{0}^{h}-E\left(\mathbf{q}_{0},V\left(\mathbf{q}_{0},y_{0}^{h}\right)\right)\right]. \tag{7.15}$$

Finally, note that the second term of the price term are the expenditures in the pre-reform situation, and hence equal to $\mathbf{q}_{0}'x_{0}^{h}$. Since the difference in pre- and post-reform prices amounts to the change in indirect taxes, we have:

$$\mathbf{q}_{1}'x_{0}^{h}-\mathbf{q}_{0}'x_{0}^{h}=\left(\mathbf{q}_{1}'-\mathbf{q}_{0}'\right)x_{0}^{h}=\left(\boldsymbol{\tau}_{1}'-\boldsymbol{\tau}_{0}'\right)x_{0}^{h}, \tag{7.16}$$

which we denote as $\Delta T_{x_0}^{h}(\boldsymbol{\tau_0},\boldsymbol{\tau}_1)$ for the change in indirect taxes paid, calculated at the original quantities.

To sum up, as a lower bound to the welfare change induced by a change in disposable income and a price change, we calculate:

$$\Delta W_{CV}^{h}\geq\left[y_{1}^{h}-y_{0}^{h}\right]-\Delta T_{x_0}^{h}(\boldsymbol{\tau_0},\boldsymbol{\tau}_1). \tag{7.17}$$

3.7.2 Using the equivalent variation

Exactly the same reasoning can be followed for the calculation of a welfare metric based on the equivalent variation concept. This is the monetary compensation a household would have to forego in the baseline, that is under the old prices $\mathbf{q}_0$, and given the old income y_0^h, in order to be indifferent between this baseline and the post-reform situation with new prices $\mathbf{q}_1$ and new income y_1^h:

$$V\left(\mathbf{q_1}, y_1^h\right) = V\left(\mathbf{q_0}, y_0^h - EV^h\right). \tag{7.18}$$

Again the value EV^h defined in equation (7.18) takes up the welfare effect of both the price change, and the change in disposable income.

To interpret the sign of EV^h, and link it to the sign of ΔW^h, note that in case of a pure price increase (and hence the same income as before), the household is prepared to give up some income not to have to undergo the new prices, and EV^h will be positive. The sign of ΔW^h, being opposite to the one of EV^h, should be negative in this case. In case of a pure change in disposable income, the sign of ΔW^h should equal that of the change in disposable income. As will be shown below, this will indeed be the case.

We solve for the value of EV^h in equation (7.18), by inverting the V-function at the RHS around its second argument. This yields the second argument of the RHS of equation (7.18) as a function of the price vector $\mathbf{q}_0$ and the value at the LHS of equation (7.18):

$$y_0^h - EV^h = E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right), \tag{7.19}$$

And hence:

$$\begin{aligned} EV^h &= y_0^h & &- E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right) \\ &= E\left(\mathbf{q}_0, V\left(\mathbf{q}_0, y_0^h\right)\right) & &- E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right) \\ &= E\left(\mathbf{q}_0, V_0^h\right) & &- E\left(\mathbf{q}_0, V_1^h\right), \end{aligned} \tag{7.20}$$

where in the second line we have used the fact that $y_0^h \equiv E\left(\mathbf{q}_0, \mathrm{V}\left(\mathbf{q}_0, y_0^h\right)\right)$. The third line of equation (7.20) shows how EV^h is a money metric of the welfare change (i.e. comparing V_0^h with V_1^h) of a price and income change, using the pre–reform prices $\mathbf{q}_0$ as reference prices in the money metric. Comparing the third line of (7.20) with how we defined the welfare change ΔW^h in (7.1) shows that:

$$\Delta W_{EV}^h = -EV^h, \tag{7.21}$$

where we have added the subscript EV to the welfare change to denote that it is obtained from the definition of the equivalent variation.

The fixing of the reference price vector, in this case at the pre-reform prices $\mathbf{q}_0$, does not remove pre-reform prices $\mathbf{q}_1$ as an argument of the welfare change. Indeed, the second line of equation (7.20) makes clear that with changes in both prices and incomes, the value EV^h

depends on all four arguments: $\mathbf{q}_0$, $\mathbf{q}_1$, y_0^h and y_1^h. For further reference, we therefore summarize the second line of equation (7.20) as:

$$EV^h = E\left(\mathbf{q}_0, V\left(\mathbf{q}_0, y_0^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right) = EV\left(\mathbf{q}_0, \mathbf{q}_1, y_0^h, y_1^h\right). \tag{7.22}$$

To decompose the welfare change ΔW_{EV}^h in the effect of the change in disposable income, and the effect of a "pure" change in prices, we make use of a specific form of equation (7.22), i.e. the one in which we keep disposable income unchanged. More specifically, let $y_0^h = y_1^h$, and hence we will denote disposable income by y_1^h. In that case, equation (7.22) reads as:

$$EV\left(\mathbf{q}_0, \mathbf{q}_1, y_1^h, y_1^h\right) = E\left(\mathbf{q}_0, V\left(\mathbf{q}_0, y_1^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right). \tag{7.23}$$

Since $y_1^h = E\left(\mathbf{q}, V\left(\mathbf{q}, y_1^h\right)\right)$ holds for any price vector $\mathbf{q}$, we can also write the first term in equation (7.23) with the post reform price vector $\mathbf{q}_1$ [4]:

$$EV\left(\mathbf{q}_0, \mathbf{q}_1, y_1^h, y_1^h\right) = E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, y_1^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right). \tag{7.24}$$

Equation (7.24) shows how the equivalent variation at constant disposable incomes, evaluates the effect of a pure price change from $\mathbf{q}_0$ to $\mathbf{q}_1$ by comparing the expenditure function for the two price vectors, evaluated at the post reform utility level $V_1^h = V\left(\mathbf{q}_1, y_1^h\right)$.

We now use (7.24) to decompose the welfare change ΔW_{EV}^h of equation (7.21) into the change of disposable income, and the welfare effect of a pure price change. Using equation (7.20), ΔW_{EV}^h can be written as:

$$\Delta W_{EV}^h = E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right) - y_0^h. \tag{7.25}$$

Adding and subtracting y_1^h yields:

$$\Delta W_{EV}^h = \left[y_1^h - y_0^h\right] - \left[y_1^h - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right)\right]. \tag{7.26}$$

Given that $y_1^h = E\left(\mathbf{q}, V\left(\mathbf{q}, y_1^h\right)\right)$, equation (7.26) can also be written as:

$$\Delta W_{EV}^h = \left[y_1^h - y_0^h\right] - \left[E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, y_1^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right)\right]. \tag{7.27}$$

[4] Note that equation (7.24) is in fact the definition of the equivalent variation appearing in many (if not most) textbooks, i.e. with income unchanged.

The welfare effect ΔW_{EV}^{h} is the sum of the change in disposable income in the first square brackets, and a "pure" price effect in the second square brackets. This "pure" price effect equals the equivalent variation at constant income equal to the post-reform level y_1^h, $EV\left(\mathbf{q}_0, \mathbf{q}_1, y_1^h, y_1^h\right)$, as defined equation (7.24):

$$\Delta W_{EV}^{h} = \left[y_1^h - y_0^h\right] - EV\left(\mathbf{q}_0, \mathbf{q}_1, y_1^h, y_1^h\right). \tag{7.28}$$

We do not dispose of an expenditure function to calculate the price term in equation (7.27). We rely on the standard approximation used in the literature. It is based on the replacing $E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right)$ in the price term of

$$\Delta W_{EV}^{h} = \left[y_1^h - y_0^h\right] - \left[E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, y_1^h\right)\right) - E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right)\right] \tag{7.29}$$

with the expenditures needed to buy the post-reform quantities $\mathbf{x}_1^{\mathbf{h}}$ at the old prices $\mathbf{q}_0$. We know that the post-reform quantities $\mathbf{x}_1^{\mathbf{h}}$ were utility maximizing, and hence cost minimizing, at the post-reform prices $\mathbf{q}_1$. But this post-reform bundle is not necessarily the cost-minimizing bundle at the old prices $\mathbf{q}_0$. Therefore, we have:

$$E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right) \leq \mathbf{q}_0' x_1^h. \tag{7.30}$$

If we replace $E\left(\mathbf{q}_0, V\left(\mathbf{q}_1, y_1^h\right)\right)$ in equation (7.29) by the number $\mathbf{q}_0' x_1^h$, which is possibly higher, the effect of the price change in equation (7.29) is possibly underestimated (i.e. the number we subtract as the second square bracket is too small). Therefore, this approximation through the RHS of equation (7.30) yields an upper bound of the exact welfare change ΔW_{EV}^{h}:

$$\Delta W_{EV}^{h} \leq \left[y_1^h - y_0^h\right] - \left[E\left(\mathbf{q}_1, V\left(\mathbf{q}_1, y_1^h\right)\right) - \mathbf{q}_0' x_1^h\right]. \tag{7.31}$$

Finally, note that the first term of the price term equals the expenditures in the post-reform situation, and hence is equal to $\mathbf{q}_1' x_1^h$. Since the difference in pre- and post-reform prices amounts to the change in indirect taxes, we have:

$$\mathbf{q}_1' x_1^h - \mathbf{q}_0' x_1^h = \left(\mathbf{q}_1' - \mathbf{q}_0'\right) x_1^h = \left(\boldsymbol{\tau}_1' - \boldsymbol{\tau}_0'\right) x_1^h, \tag{7.32}$$

which we denote as $\Delta T_{x_1}^{h}(\boldsymbol{\tau}_0, \boldsymbol{\tau}_1)$ for the change in indirect taxes paid, *calculated at the post-reform quantities*.

To sum up, as an upper bound to the welfare change induced by a change in disposable income and a price change, we calculate:

$$\Delta W_{EV}^{h} \leq \left[y_1^h - y_0^h \right] - \Delta T_{x_1}^{h}(\boldsymbol{\tau_0}, \boldsymbol{\tau}_1) . \quad (7.33)$$

3.7.3 Implementation in ITT

To calculate welfare measures with ITT, first, we need the change in disposable income: $\left[y_1^h - y_0^h \right]$; this will come directly out of EUROMOD.

Second, we need the difference in indirect taxes paid, calculated in two ways:

- As the difference in expenditures for the pre-reform quantities: $\Delta T_{x_0}^{h}(\boldsymbol{\tau_0}, \boldsymbol{\tau}_1)$. This will be obtained directly as the difference in expenditures from a simulation where we keep the quantities fixed.
- As the difference in expenditures for the post-reform quantities: $\Delta T_{x_1}^{h}(\boldsymbol{\tau_0}, \boldsymbol{\tau}_1)$. The new quantities are obtained by assuming constant budget shares. EV of a "price change" should be possible to calculate as follows:

$$\Delta T_{x_1}^{h}\left(\tau_0, \tau_1\right) = \sum\nolimits_G \Delta T_{x_{G,1}}^{h}\left(\tau_{G,0}, \tau_{G,1}\right) = \sum\nolimits_G \sum\nolimits_{k \in G} x_{k,1}^{h}\left(q_{k,1} - q_{k,0}\right), \quad (7.34)$$

where G denotes aggregate commodity group and k each detailed commodity in group G. Given that $e = qx = \left(1 + \tau\right) px$ and our assumption GA.2 of constant producer prices $\left(p_0 = p_1\right)$, we can rewrite:

$$x_{k,1}^{h}\left(q_{k,1} - q_{k,0}\right) = e_{k,1}^{h} - \frac{e_{k,1}^{h}}{\left(1 + \tau_{k,1}\right) p_1}\left(1 + \tau_{k,0}\right) p_0 = e_{k,1}^{h}\left(1 - \frac{1 + \tau_{k,0}}{1 + \tau_{k,1}}\right). \quad (7.35)$$

Second, recall assumption GA.0 about the budget shares of individual commodity within an aggregate category corresponding to the population-level shares observed in the HBS. Combining (5.4) with equations above, we obtain

$$\Delta T_{x_1}^{h}\left(\tau_0, \tau_1\right) = \sum_{G} \sum_{k \in G} e_{k,1}^{h}\left(1 - \frac{1 + \tau_{k,0}}{1 + \tau_{k,1}}\right) = \sum_{G} e_{G,1}^{h} \sum_{k \in G} \omega_{k,HBS}\left(1 - \frac{1 + \tau_{k,0}}{1 + \tau_{k,1}}\right). \quad (7.36)$$

We then add together the "income change" and the "price change" to get the total effect on household welfare.

4. COMPARATIVE TECHNICAL INFORMATION

This section provides a selection of cross-country comparisons, that complements the more detailed description and validation exercise inserted in each of the ten country reports. We start by looking at the features of the input HBS data used in the estimation phase, and at the scope of the ITT. The second part of this section compares how well the model predicts household expenditures and indirect taxes paid, as compared to the official macro statistics.

4.1 Selected issues and validation of input data

The data used for the estimation is the Household Budget Survey, from 2011 or 2012, except for Belgium (using 2014 data) and Austria (using 2009/10 data). The base year for the SILC-survey is 2012, with 2011 incomes for all countries.

Table 6: Survey and income year of SILC and HBS

		BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
HBS	Survey year	2014	2011	2011	2011	2011	2009-10	2011	2011	2012	2012
	Income year	2014	2011	2011	2011	2011	2009-10	2011	2011	2012	2012
SILC	Survey year	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012
	Income year	2011	2011	2011	2011	2011	2011	2011	2011	2011	2011

The Indirect Tax Tool allows to user to choose the index for the indexation for the imputation phase. The indexes that are currently available in the model are listed in Table 7. Users can manually add yet other indices to the model.

Table 7: Survey and income year of SILC and HBS

	BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
oecd_cat1			Default	Default	Default				Default	Default
oecd_p31nc			x		x				x	
CPI	Default	Default	x	x	x	Default	Default	Default	x	x
gdp_current			x		x				x	

As explained in the methodology section, a two-stage estimation procedure is used to estimate the expenditures on durable goods and the estimation of the expenditures on the commodity groups that are characterised by a large proportion of households not consuming any commodity within the group, the so called ‘zero categories’. Table 8 lists an overview of the percentage of households that do not consume any of the goods/services within the different commodity groups. The cells highlighted in green are the commodity groups for which a two-stage estimation procedure was used. In most countries *Alcoholic beverages*, *Tobacco products*, *Public transport*, *Education* and to a lesser extent *Housing & rents* and *Restaurants and hotels* are the categories selected for a two-stage Engel curve estimation, rather than a one stage OLS estimation.

Table 8: Zero expenditures (% of households who do not consume a commodity)

	BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
Food and non-alcoholic beverages	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.8
Alcoholic beverages	29.5	4.1	49.0	43.0	58.0	41.3	41.7	52.7	42.1	46.9
Tobacco	72.8	61.6	74.1	61.8	74.7	65.8	69.5	69.4	76.4	79.3
Clothing and footwear	20.0	0.4	58.6	21.2	48.9	29.5	30.0	47.6	38.4	34.7
Home fuels, electricity and water	0.0	1.7	3.1	0.2	0.1	0.6	3.1	2.4	1.8	0.3
Housing and rents	66.3	42.7	39.5	40.3	28.2	41.9	37.6	92.5	8.5	34.0
Household goods and services	6.6	0.1	34.8	5.5	31.0	21.1	6.0	13.0	9.5	15.8
Health	16.1	0.8	51.6	16.3	38.4	24.4	17.7	41.3	11.9	48.0
Private transport	17.3	21.9	61.7	35.0	59.4	16.9	43.4	75.3	10.3	20.6
Public Transport	75.5	13.7	75.6	55.6	60.8	58.6	62.8	73.0	64.9	64.2
Communication	1.4	0.1	5.8	1.6	9.0	37.2	4.0	21.1	0.6	4.5
Recreation and culture	3.7	0.3	15.7	0.5	14.3	6.2	5.2	6.7	0.2	1.2
Education	86.4	56.6	92.7	76.6	89.4	75.1	89.2	98.1	65.5	93.4
Restaurants and hotels	16.5	6.8	67.6	15.2	56.4	12.8	68.1	92.6	24.5	12.8
Other goods and services	0.1	1.4	16.1	3.0	6.1	0.8	0.6	17.6	0.4	2.2
Durable goods	1.3	5.4	37.4	41.5	52.7	11.5	42.7	78.2	6.7	32.7

Notes: green shades = commodity group is categorised as a 'zero category'.
Source: Household budget surveys BE, CZ, EE, EL, LV, AT, PL, RO, FI, UK.

The scope of the indirect tax simulations covers all the applicable VAT rates - the standard VAT rates and the main reduced rates - and the most important excises (applicable to goods consumed by households). The ITT covers the standard rate, the reduced rate(s), and the zero VAT-rate and the VAT-exempted goods. Since we assume full pass through of indirect taxes on to the consumer, the model does not distinguish between a zero rate and VAT exemption. Concerning the excises, the large majority (in terms of importance in the tax revenue) are indeed included in the model (see Table 9 for an overview).

Table 9: Scope of simulations

	BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
VAT										
Standard rate	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Reduced rate 1	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Reduced rate 2	sim	sim	n/a	sim	n/a	sim	sim	sim	sim	n/a
Zero rate & exempted	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Excises										
Alcohol	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Tobacco	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
(Motor) fuels	sim	sim	sim	sim	sim	sim	sim	sim	sim	sim
Heating	sim	sim	n/a	sim	sim	sim	sim	sim	sim	sim
Electricity	sim	sim	sim	sim	n/a	sim	sim	sim	sim	sim
Packaging	ns	n/a	ns	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Non-alcoholic beverages	ns	n/a	n/a	n/a	sim	n/a	n/a	n/a	sim	n/a
Coffee	sim	n/a	n/a	n/a	sim	n/a	n/a	n/a	n/a	n/a
Sweets, gums, ice creams	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	sim	n/a
Betting games	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	sim
Insurance premiums	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	sim

The level of detail with which we can model the exact scope of the VAT system critically rests on the detail retained in the HBS. If there's no commodity level information on a specific good, the

ITT cannot simulate an excise change for that good, e.g. cigars for some countries. Most countries also lack detailed information on alcohol consumed in bars or restaurants.

4.2 Validation of the ITT outcomes

Tax rates vary greatly across product categories and across countries. In Table 10 we list the implicit tax rates for the main expenditure categories. In each of the 10 countries, *tobacco products* are taxed most, with tax rates varying from 80.4% in Poland up to 566.6% in Estonia. *Alcoholic beverages* come in second, with implicit tax rates varying between 39.3% in Romania and 100.7% in Finland; and *private transport* is the third highest taxed (between 39.2% in Poland and 117.3% in the Czech Republic). Finland is the only country for which another commodity, other than the three mentioned groups, has an implicit tax rate higher than 25%, being *home fuels, electricity and water*. The variation in tax rates of the other commodity categories is driven largely by whether or not the specific commodities within the categories are subject to reduced VAT rates.

Table 10: Implicit tax rates (as % of producer prices, 2011 policies)

	BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
Food and non-alcoholic beverages	6.1	10.3	20.0	13.0	22.5	11.0	6.7	24.0	14.1	2.4
Alcoholic beverages	39.6	36.7	81.5	74.3	78.0	40.3	47.6	39.3	100.7	70.7
Tobacco	250.8	428.8	566.6	472.4	479.7	287.0	80.4	94.4	342.1	301.9
Clothing and footwear	21.0	20.0	20.0	23.0	22.0	20.0	17.1	24.0	23.0	16.1
Home fuels, electricity and water	20.6	17.8	23.4	13.9	19.0	17.0	17.9	24.5	41.4	3.7
Housing and rents	0.0	0.0	13.1	3.8	14.1	10.9	15.9	9.4	0.3	0.5
Household goods and services	17.5	19.5	20.0	23.0	22.0	20.0	18.7	24.0	23.0	20.0
Health	1.8	6.1	5.9	13.0	7.8	12.7	4.9	6.9	7.2	4.1
Private transport	48.5	117.3	60.5	104.9	65.1	45.6	39.2	71.9	51.1	78.0
Public Transport	6.0	10.4	20.0	13.0	14.4	10.4	7.7	24.0	6.5	3.3
Communication	20.5	20.0	19.7	22.7	21.8	10.2	18.5	24.0	22.4	18.9
Recreation and culture	14.8	17.0	18.2	11.5	18.5	13.9	11.4	5.5	11.3	14.1
Education	0.0	0.5	4.3	0.0	0.0	0.0	0.0	0.0	12.6	0.0
Restaurants and hotels	8.2	20.1	18.9	21.8	17.5	8.3	11.9	20.5	15.6	22.2
Other goods and services	2.6	4.7	10.9	13.7	14.9	9.2	13.3	18.3	13.1	14.0
Durable goods	20.2	13.2	19.2	23.0	22.0	20.0	18.9	24.0	23.0	17.9

Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

In order to macro-validate the model outcomes, we look at how total imputed expenditures and simulated taxes compare to the macro statistics and national accounts. Table 10 presents the coverage rates of total expenditures and indirect taxes by commodity, while Table 11 looks more closely at how the imputed expenditures match the household expenditures for each of the 16 commodity groups.

As shown in Table 11 coverage rates of the total household expenditures, at the population level, range from 48.7% in Poland, to 91.2% in Finland. Coverage of simulated total indirect taxes range from just 37.1% for Poland, and 62.0% in Latvia. As can be expected from the fact that most VAT is paid by households, coverage rates for VAT are consistently higher, ranging from 44.4% in Poland, to 75.0% in Latvia. Coverage rates of excises are low across the board (with the exception of alcohol excises in Austria). Two explanations for these low coverage rates are that (1) non-households consume goods subject to excises, just like households, and these expenditures are excluded from the model; and (2) the tax base for excises paid by households itself is generally underestimated in the source data (see Table 12). We have not quantified the respective contribution of both of these factors to the underestimation of simulated taxes. In countries were black market sales for some products are important, this factor would work opposite of the previous two: as the ITT assumes complete tax-compliance, hence in the face of actual indirect tax evasion the ITT will -ceteris paribus- oversimulate the indirect taxes with respect to actual revenue.

Saving rates deduced from the HBS and imputed EUROMOD output are – overall – higher than the official household savings from the national accounts, the exceptions being Belgium, Austria and the UK. Taking 2011 as a reference year, Eurostat even reports negative savings for Latvia, and while it gave no estimate for Greece, the OECD estimated the household savings to be negative as well, whereas the aggregate saving rates based on the microdata are positive. More research is needed to enhance our understanding of diverging coverage rates, and differences in saving rates.

Table 11: Coverage of expenditures and tax revenues (% of national statistics)

	BE	CZ	EE	EL	LV	AT	PL	RO	FI	UK
Total expenditure	82.6	64.8	58.1	54.5	60.9	79.5	48.7	n/a	91.2	79.8
Total indirect taxes	50.3	41.1	41.1		62.0	61.3	37.1	37.7	46.0	54.2
VAT (total)	65.0	50.5	50.6	56.0	74.0	67.7	44.4	44.8	57.0	64.4
VAT (hh sector)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	75.0	n/a
Excises	41.0	23.7		33.0	37.0	41.3	23.0	20.0	26.7	40.0
- alcohol	46.9	16.3	15.0		21.0	105.1	n/a	n/a	35.0	33.0
- tobacco	29.3	23.2	27.8		49.0	63.8	n/a	n/a	43.3	47.6
- energy	43.6					31.4	n/a	n/a	n/a	n/a
- fuel			24.4		n/a		n/a	n/a	43.0	65.0
- home fuel		16.3	n/a		n/a		n/a	n/a	n/a	n/a
- car fuel		26.0	n/a		n/a		n/a	n/a	n/a	65.0
- sweets, ice cream and/or soft drinks				n/a	n/a		n/a	n/a	70.6	n/a
- betting & gaming				n/a			n/a	n/a	n/a	35.0
- insurance premium tax				n/a			n/a	n/a	n/a	54.0
Savings rate (% of total income)										
In HBS	15.1	n/a	23.7	11.2	2.7	13.7	32.2	17.4	n/a	21.3
Imputed in SILC	11.4	22.3	31.8	15.0	5.7	6.9	34.2	12.5	15.8	8.1
Eurostat statistics (2011)	13.5	11.2	9.9	$-8.9^{(*)}$	-3.9	13.3	1.5	n/a	8.1	8.9

Notes: Colour shades: darker green = less underestimated w.r.t. national accounts, darker red = greater underestimation.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0, Eurostat (and OECD for (*)).

Table 12 presents coverage rates for the 16 commodity groups separately. Some countries perform better than others, but apart from the UK which outperforms the other countries and scores good overall, the coverage rate varies greatly across the commodity groups. As can be expected from the prior observation that the coverage rates of total expenditures are below 100% in all countries, coverage rates for most commodity groups are below 100% as well, with some exceptions situated in the categories *Housing and rents*, in *Household goods and services*, in *Communication*, and *Durable goods*. *Alcoholic beverages* and *Tobacco products* perform the worst. *Other goods and services*, *Public transport* and *Restaurants and hotels* are other poor performing commodity groups. In part this can be explained by the measurement error within the HBS, in part by the use of different definitions for the national accounts concepts, and the selection basis for the creation of the commodity groups. For example international air/train travel is included in the public transport category according to the COICOP-classification, but was left out of this category for the estimation process.

Table 12: Share of HBS expenditures versus National Accounts (% of national accounts)

	BE	CZ	EE	EL	LV	AT	PL	FI	UK
Food and non-alcoholic beverages	84.5	79.4	69.7	70.9	98.3	93.5	61.7	91.7	93.3
Alcoholic beverages	69.2	21.3	18.6	69.3	26.8	62.2	15.6	43.7	82.4
Tobacco	27.3	20.7	24.5	50.2	48.7	53.9	n/a	42.2	79.2
Clothing and footwear	86.6	93.0	39.8	98.8	40.3	72.0	56.4	64.0	87.2
Home fuels, electricity and water	90.7	83.4	98.9	89.5	110.5	94.8	63.2	102.7	87.1
Housing and rents	78.7	76.5	144.4	83.6	172.7	106.0	43.1	131.8	94.9
Household goods and services	167.1	475.4	159.4	96.4	165.3	63.0	55.4	74.9	94.2
Health	56.2	61.8	62.7	94.1	66.6	73.0	54.1	66.2	98.8
Private transport	69.3	58.1	48.1	105.8	45.5	79.5	46.3	103.3	85.8
Public Transport	31.7	51.9	21.8	12.2	178.8	29.6	24.4	67.8	81.4
Communication	111.3	117.5	83.3	58.0	143.6	63.9	68.1	95.2	95.1
Recreation and culture	55.7	61.2	56.9	55.9	101.7	56.3	40.3	72.4	97.2
Education	111.3	88.5	59.4	87.8	67.6	98.4	43.0	44.8	133.3
Restaurants and hotels	126.1	20.5	29.8	55.3	53.8	61.6	57.2	77.0	92.0
Other goods and services	56.4	6.2	34.6	52.7	65.7	67.6	18.9	80.6	91.6
Durable goods	135.7	84.8	77.3	77.9	99.3	119.9	36.6	118.4	58.3

Notes: Colour shades: darker blue =greater overestimation w.r.t. national accounts, darker red = greater underestimation.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0, OECD data.

5. POLICY REFORM ANALYSIS: A TAX SHIFT FROM DIRECT TO INDIRECT TAX

This section analyses a policy reform which shifts tax revenue from direct to indirect taxes and shows its distributive effects in the 10 countries for which we develop indirect tax policy simulation in EUROMOD. The proposed reform reduces national income tax rates by one percentage point in all 10 countries, in 2015. We then introduce a compensating reform, which increases taxes on commodities enough to balance the overall government budget. Goods and services subject to zero rate or exempt from VAT remain unchanged under the reform scenario. Hence this reform -by contruction- balances the government budget, but distibutional effects will persist. These simulations are chosen as simple illustrations of what the model can do. For a general description on how to analyse this illustrative policy reform of indirect taxes using the new EUROMOD indirect tax tool (ITT v1.0.0) see the User Manuel (Annex 1).

In order to achieve budget neutrality, we calibrate for each country a certain percentage point increase of all non-zero (and non-exempt) VAT rates, such that we achieve budget neutrality. The VAT rates in baseline and reform are shown in Table 13.

Table 13: Statutory VAT rates in baseline and in reform (percentage)

	Baseline 2015				Reform 2015				Percentage point change
	Zero	Super-reduced	Reduced	Standard	Zero	Super-reduced	Reduced	Standard	
AT	0	10	12	20	0	10.78	12.78	20.78	0.78
BE	0	6	12	21	0	7.29	13.29	22.29	1.29
CZ	0	10	15	21	0	12.05	17.05	23.05	2.05
EE	0		9	20	0		10.54	21.54	1.54
EL	0	6.5	13	23	0	7.16	13.63	23.63	0.63
FI	0	11	15	25	0	12.00	16.00	26.00	1.00
LV	0		12	21	0		13.26	22.26	1.26
PL	0	5	8	23	0	7.17	10.17	25.17	2.17
RO	0	5	9	24	0	6.22	10.22	25.22	1.22
UK	0		5	20	0		6.47	21.47	1.47

We first look at the effects that these reforms would have on government budgets in the ten countries, comparing the outcomes under Constant Shares behavioural scenario. The results are presented in Table 14 where we present all changes with respect to the 2015 baseline, both in nominal terms and in percentage changes.

The Constant Shares behavioural assumption implies that households spend the same proportion of income on each expenditure category in the baseline and the reform. Since disposable income increases because of lower personal income taxes, total household expenditures will increase as well. The increase in prices (due to the VAT increase) causes households to alter their spending structure (in the current period) such that they move away from goods that show implicit price increases towards goods that became relatively cheaper. Note that substitution effects toward (or away from) goods on which other indirect taxes are levied implies that we can observe some changes in revenue from excises as well.

Table 14 shows that this policy reform is budget neutral in all countries. For example, by decreasing income tax by one percentage point, Austria would reduce revenue by 800 million euros, which may be recovered by rising all non-zero VAT rates by 0.78 percentage points. For the Czech Republic, on top of changes in direct and indirect taxes, we can observe a change in means tested benefit as a consequence of reducing income tax. This is because of a refundable child tax credit (treated as means tested benefit) which becomes higher as a consequence of the reform. In all other countries, except Greece, we can observe a very small decrease in means-tested benefits, which follows from an increase of the net income concept used for the means test.

Table 14: Budgetary effects of a VAT rise and income tax decrease in ten European countries in 2015 (annual aggregate amounts in million per year)

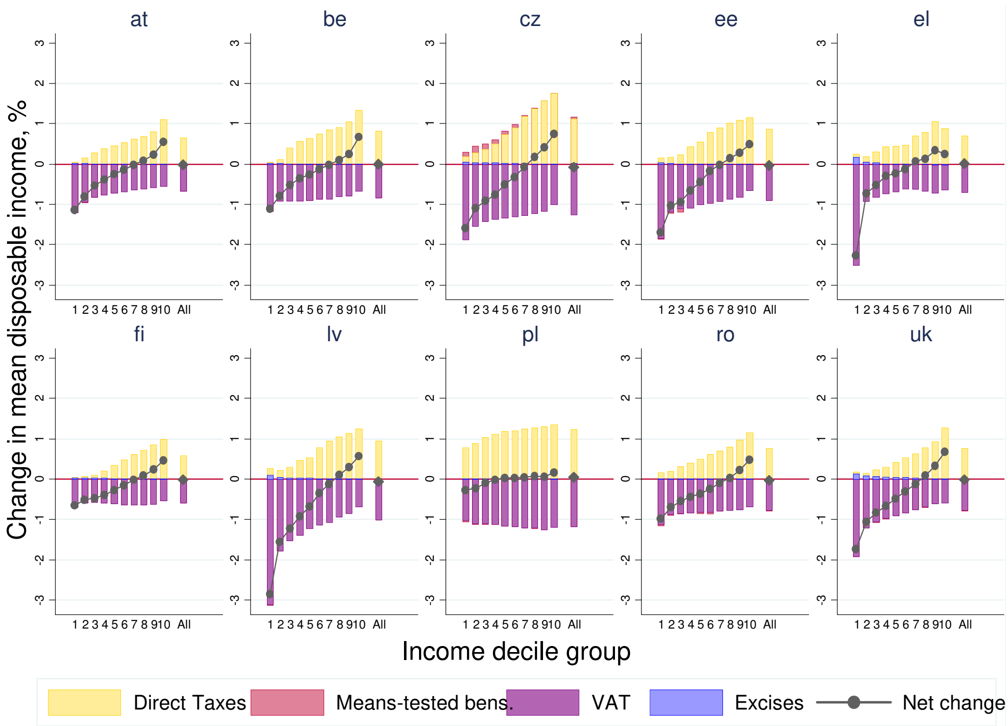
		Total Revenues				Total Expenditures				Budget effect
		Total	Personal inc. tax	NIC	Indirect taxes	Total	MT benefits	Non-MT benefits	Public Pensions	
Austria	Baseline	79936	32501	27347	20087	58428	4696	9172	44560	21507
	Reform	79930	31695	27347	20887	58426	4694	9172	44560	21504
	Difference	-5.4	-805.6	0.0	800.3	-2.3	-2.3	0.0	0.0	-3.1
	Diff. %	0.0	-2.5	0.0	4.0	0.0	-0.1	0.0	0.0	0.0
Belgium	Baseline	85813	45332	22725	17756	60371	6996	7885	45489	25442
	Reform	85813	44175	22725	18912	60370	6996	7885	45489	25442
	Difference	-0.1	-1156.6	0.0	1156.4	-0.1	-0.1	0.0	0.0	0.0
	Diff. %	0.0	-2.6	0.0	6.5	0.0	0.0	0.0	0.0	0.0
Czech Republic	Baseline	565483	129583	228371	207530	471250	25094	54766	391390	94233
	Reform	566438	113992	228371	224075	472200	26044	54766	391390	94237
	Difference	954.3	-15590.9	0.0	16545.2	950.2	950.2	0.0	0.0	4.1
	Diff. %	0.2	-12.0	0.0	7.97	0.2	3.8	0.0	0.0	0.0
Estonia	Baseline	2715	1276	356	1084	2235	47	632	1556	480
	Reform	2714	1213	356	1146	2235	47	632	1556	480
	Difference	-0.5	-62.8	0.0	62.3	-0.5	-0.5	0.0	0.0	0.0
	Diff. %	0.0	-4.9	0.0	5.8	0.0	-1.1	0.0	0.0	0.0
Greece	Baseline	38484	11720	10922	15842	30200	2103	1198	26899	8284
	Reform	38485	11325	10922	16237	30200	2103	1198	26899	8285
	Difference	0.7	-394.9	0.0	395.6	0.0	0.0	0.0	0.0	0.7
	Diff. %	0.0	-3.4	0.0	2.5	0.0	0.0	0.0	0.0	0.0
Finland	Baseline	49857	28499	7282	14076	36360	5294	5532	25533	13497
	Reform	49857	28001	7282	14575	36360	5294	5532	25533	13498
	Difference	0.3	-497.9	0.0	498.3	-0.2	-0.2	0.0	0.0	0.6
	Diff. %	0.0	-1.8	0.0	3.5	0.0	0.0	0.0	0.0	0.0
Latvia	Baseline	4075	1666	917	1492	2494	57	559	1877	1581
	Reform	4075	1597	917	1562	2494	57	559	1877	1581
	Difference	-0.1	-69.6	0.0	69.5	0.0	0.0	0.0	0.0	0.0
	Diff. %	0.0	-4.2	0.0	4.7	0.0	-0.1	0.0	0.0	0.0
Poland	Baseline	296895	128489	95136	73270	233068	7804	14808	210456	63826
	Reform	296880	121334	95136	80410	233047	7783	14808	210456	63833
	Difference	-14.5	-7155.4	0.0	7140.8	-21.0	-21.0	0.0	0.0	6.4
	Diff. %	0.0	-5.6	0.0	9.8	0.0	-0.3	0.0	0.0	0.0
Romania	Baseline	73727	30019	16963	26745	62992	5323	7155	50514	10735
	Reform	73707	28834	16963	27911	62972	5303	7155	50514	10735
	Difference	-19.1	-1184.8	0.0	1165.7	-19.4	-19.4	0.0	0.0	0.3
	Diff. %	0.0	-4.0	0.0	4.4	0.0	-0.4	0.0	0.0	0.0
United Kingdom	Baseline	323351	153813	62155	107383	189805	67487	44883	77435	133545
	Reform	323320	148812	62155	112353	189788	67470	44883	77435	133532
	Difference	-30.8	-5000.8	0.0	4970.1	-17.3	-17.3	0.0	0.0	-13.5
	Diff. %	0.0	-3.3	0.0	4.6	0.0	0.0	0.0	0.0	0.0

Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

The distributional effect of the reform under Constant Shares behavioural assumption is shown in Figure 2. VAT is known to be a regressive tax which affect lower income households proportionally more than higher income households. The compensation policy reform that we used, cutting personal income tax, is not compensating low income families as most of those at the bottom pay little or no personal income tax, making the regressive effect of the shift between direct and indirect tax even stronger. The pictures do not change when looking at Constant Quantities behavioural assumption. It is clear from the distribution figures that on average, low income households in Latvia would see the highest losses from VAT increase, followed by Greek, Czech Republic and UK low income households.

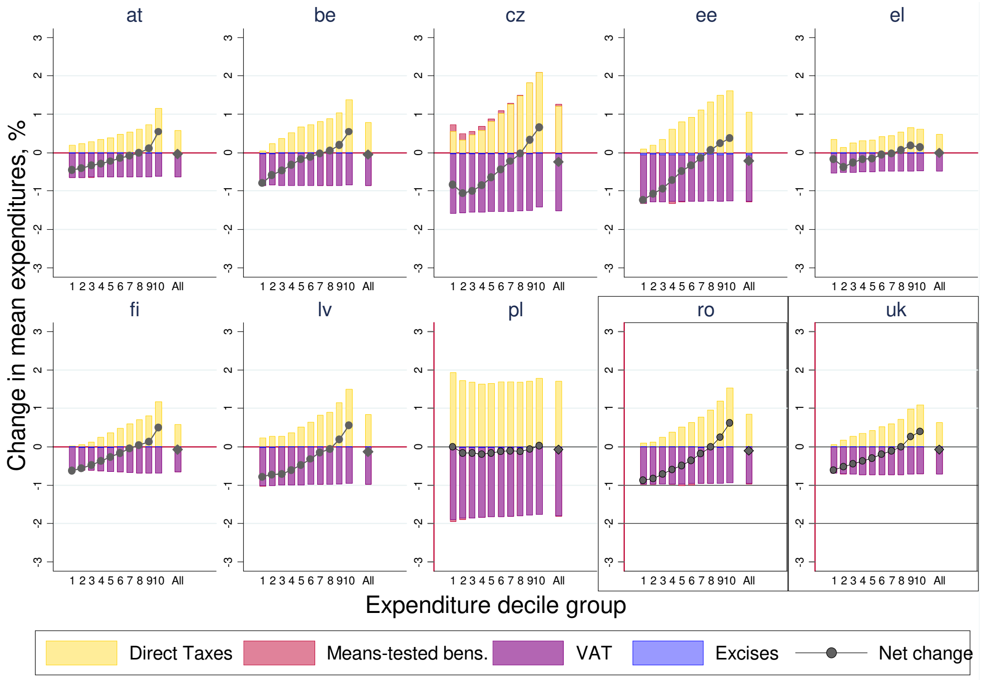
Poland is the odd duck, as here the net effect of the reform appears to be proportional, rather than regressive (this is discussed more in detail in the Polish country report). The results expressed in terms of total expenditures (as opposed to disposable income) are shown in Figure 3. The effects generally mirror the trends from the analysis with respect to income, be it that the results are somewhat less regressive.

Figure 2 Distributional effects of a shift from direct to indirect taxes in 2015: percentage changes of equivalised household income by income decile – constant shares



Notes: Deciles are based on equivalised baseline household disposable income in 2015. Change is measured as a percentage of mean baseline income after indirect taxes in 2015.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

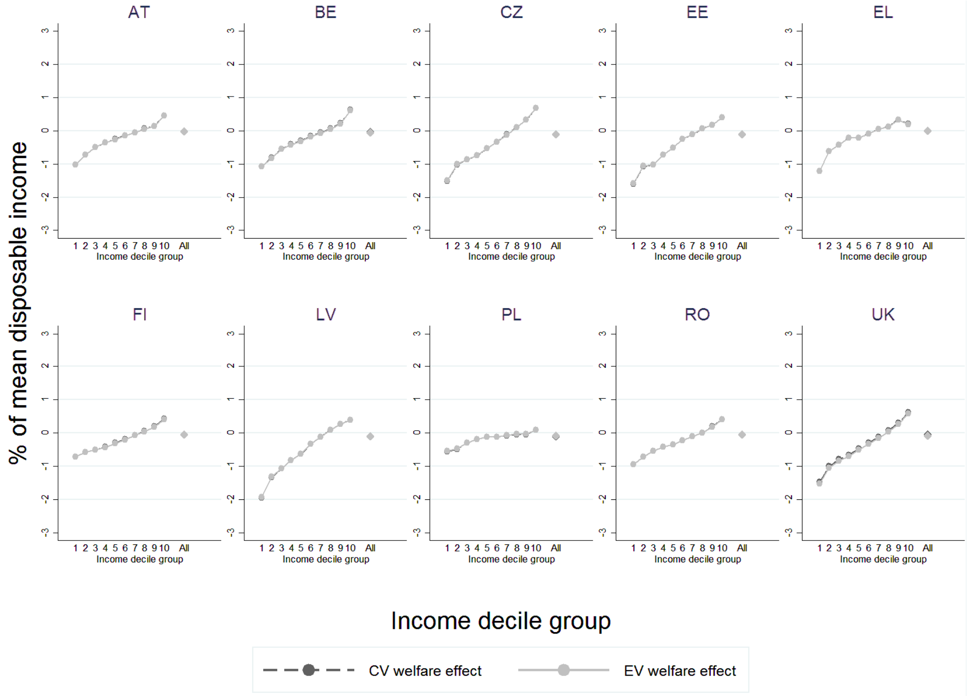
Figure 3 Distributional effects of a shift from direct to indirect taxes in 2015: percentage changes of equivalised household expenditures by expenditure decile – constant shares



Notes: Deciles are based on equivalised baseline household expenditure in 2015. Change is measured as a percentage of mean baseline income after indirect taxes in 2015.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

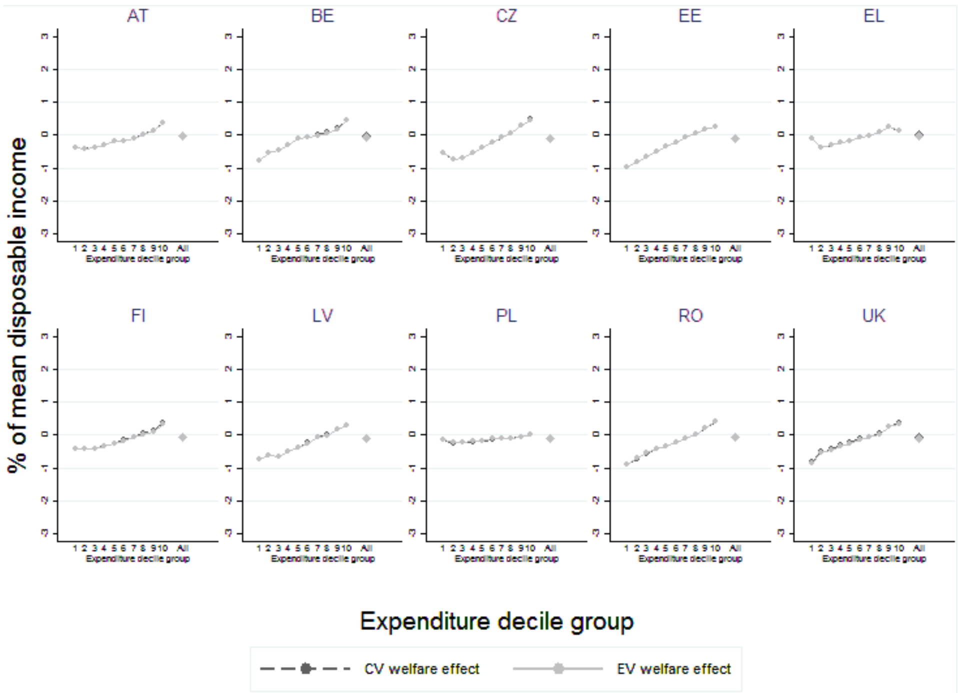
Looking at the welfare effects, as defined by the welfare concepts from section 3.7, a first general observation is that their distribution is very similar to the *net change* concept (income gain form the change in direct tax minus increase in indirect tax) as depicted in Figure 2 and Figure 3. Secondly, the choice for using the of welfare metric, using either the compensating variation or equivalent variation, does not greatly impact the results. As can be seen in Figure 4 and Figure 5 the welfare effects show very similar (regressive) patterns and levels across countries. In most countries, the reform affects the bottom and middle deciles negatively, whereas–in general- the highest three deciles are affected positively. As mentioned above, Poland is different in that the reform affects the households much more equally across the income (and expenditure) distribution.

Figure 4 Mean household welfare effect change as proportion of income by income decile: compensating and equivalent variation welfare effects



Notes: Deciles are based on equivalised baseline household disposable income in 2015. Change is measured as a percentage of mean baseline income in 2015.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

Figure 5 Mean household welfare effect change as proportion of income by expenditure decile: compensating and equivalent variation welfare effects



Notes: Deciles are based on equivalised baseline household expenditure in 2015. Change is measured as a percentage of mean baseline income in 2015.
Source: Own simulations using EUROMOD G4.2+ and ITTv1.0.0.

6. CONCLUSIONS

The aim of this project was threefold: (1) to enhance Indirect Tax Tool (ITT) in EUROMOD, which provides the capacity to simulate indirect taxes in the model, (2) to analyse the indirect tax systems for ten EU countries (Austria, Belgium, Czech Republic, Estonia, Greece, Finland, Latvia, Poland, Romania, and the UK), and (3) to prepare the necessary input for users to use the tool for these ten countries.

ITT has been improved significantly in a number of ways. To start with, the tool now allows for a consistent way of simulating expenditures and indirect taxes when there are changes in the direct tax system (either with or without changes in the indirect tax system). In the first version of the model, some of the key modelling assumptions were violated while simulating such joint reforms, in the new ITT version the assumptions have been revised and are consistently maintained throughout the whole simulation process. Second, the tool has become significantly more user-friendly and better structured: a new layout and a more intuitive interface make the learning curve less steep and the model less susceptible to errors. Finally, the tool is equipped with newly developed analytics which generate a number of output tables, providing the user with the most important synthesis on the budgetary effects as well as detailed output on the distributional effects. The analytics have also been extended with welfare measures for reforms, providing users with money-metric outcome variables quantifying the combined effect of income and price changes.

The country reports contain a detailed synopsis of the VAT and excises systems in each of the ten countries. Each of the reports contains a complete validation of the input data, as well as of the outputs produced by the model. The model comes with an expanded EUROMOD policy spine for each of the countries, as well as a set of input files that allow for simulations of 2011-2016 indirect tax systems for each of the countries. Additional policy years can be added by the user.

There are several caveats to keep in mind when applying ITT. First, our macro-validation results point to considerable gaps between national accounts on the one hand, and the simulated expenditures (and observed ones in the HBS) on the other. More research is needed to provide detailed answers as to why micro- and macro-based estimates often substantially deviate from each other and whether these may affect cross-country comparability. This also ties into the observation of the savings rates being different from the national statistics and, among others, could be related to the issue of tax compliance. Once the main drivers for these differences are better understood, a further development of the model could consider allowing users to gross up (or down) some of the expenditures to bring them in line with national accounts. Second, there appears to be a trade-off between aligning imputed expenditures in levels and imputed savings rate with those in the HBS, as the income distribution in the HBS and SILC/EUROMOD can differ substantially. It is not possible to target both at the same time and we have prioritised aligning imputed expenditures in the baseline simulations with observed expenditures in the HBS. As this relies on rescaling the income distribution (when used as an explanatory variable), it currently prohibits the use of Engel curves in the simulation process. Third, behavioural assumptions currently employed in the reform scenarios (constant quantities and constant shares) imply the same expenditure elasticities (0 and 1, respectively) for everyone on the margin. It might be desirable to allow for heterogeneous responses in the future.[5] Another area where ITT may be advanced is its assumption that changes in indirect taxes are passed on entirely to the consumer (constant producer prices). Potential routes to relax this assumption, for each commodity group separately, should be explored. A final area where further improvements are warranted concerns the nature of indexation, which is employed when there are gaps between the reference year of expenditures and EUROMOD incomes. On a more technical level, future developments could include further modularisation of ITT, to enable calling it from e.g. a Stata do-file, and to allow users to run simulations for multiple countries and/or years at once. Future projects should attempt to address these challenges as well as aim for regular updating of indirect tax policy rules and estimation of expenditure functions on more recent Household Budget Surveys as they become available.

7. References

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[5] Note that the distributional effects are mainly driven by the baseline variation in total expenditure and income levels, and therefore captured by the model. Among others, this is reflected in differential savings rates across the income distribution.

8. ANNEXES

Annex 1 – User Manual

Annex 2 – Country Report: Belgium

Annex 3 – Country Report: Czech Republic

Annex 4 – Country Report: Greece

Annex 5 – Country Report: Estonia

Annex 6 – Country Report: Latvia

Annex 7 – Country Report: Austria

Annex 8 – Country Report: Poland

Annex 9 – Country Report: Romania

Annex 10 – Country Report: Finland

Annex 11 – Country Report: United Kingdom