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# FIDELIO 3 manual: Equations and data sources

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Note: TNO stands for Netherlands Organisation for Applied Scientific Research. JRC stands for Joint Research Centre.

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## Preface

The following technical report describes the structure, the equations and the data that constitute the model FIDELIO 3.

FIDELIO is a multi-sectoral model developed by the unit B.5 of the Directorate General Joint Research Centre (JRC) — the circular economy and industrial leadership unit. The model is designed to evaluate sustainable production and consumption policies through a dynamic econometric input-output model. It conducts scenario analysis on the costs and impacts of policy measures providing their economic — such as jobs, value added and investment — and environmental effects — such as resource use or air emissions. The model can be used for policy formulation and evaluation to assess sustainable production and consumption policies capturing both spillover and rebound effects, and quantifying their impacts in jobs, growth, energy savings, investments, resource use, air emissions and trade balance.

FIDELIO 3 was preceded by two previous versions. The changes introduced in the subsequent versions of the model have two main objectives. The first one is to increase the coverage of the model. The second one is to improve the efficiency and the capacity of the model to evaluate sustainable production and consumption policies. FIDELIO 1 was created between 2009 and 2011 through the collaboration of the JRC B.5 unit and the Austrian institute of economic research WIFO (Kratena et al., 2013). Next, between 2011 and 2015, the two institutions worked on a new version of the model, FIDELIO 2, which included more countries, an update of the data and the model calibration, and some improvements of the environmental block (Kratena et al., 2017). FIDELIO 3 is the result of the collaboration of the unit B.5 of the JRC and the Dutch research organization TNO that took place in 2018 and 2019. This last version further improves the geographical coverage, both in terms of number of countries and quality of details and it updates the calibration of the model using data for 2010. Finally, compared to the previous one, this version includes important changes to the production block.

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# List of acronyms and symbols

| | |
|---|---|
| B2A3N | Net operating surplus |
| B2A3G | Gross operating surplus |
| BP | Basic prices |
| CGE | Computational general equilibrium model |
| $CH_4$ | Methane |
| CIF | Cost-insurance-freight prices |
| $CO_2$ | Carbon dioxide |
| CPA | Classification of products by activity |
| COICOP | Classification of individual consumption according to purpose |
| D1 | Compensation of employees |
| D11 | Wages |
| D12 | Social security contributions |
| D29x39 | Production taxes less subsidies |
| D4 | Property income |
| D5 | Taxes paid by households |
| D61 | Social security contributions paid by employees |
| D62 | Transfers received by households |
| D7 | Other transfers |
| ELIOD | Environmental and labour accounts linked to a global input-output database |
| FIDELIO | Fully Interregional dynamic econometric input-output model |
| FOB | Free-on-board prices |
| GRAS | Generalized RAS method |
| IEA | International energy agency |
| IO | Input-output |
| ISIC Rev. 4 | International standard industrial classification, revision 4 |
| ITTM | International transport and trade margins |
| NACE Rev. 2 | Statistical classification of economic activities, revision 2 |
| NPISH | Non-profit institutions serving households |
| $N_2O$ | Nitrous oxide |
| P51C | Depreciation |
| PP | Purchaser prices |
| QAIDS | Quasi-almost ideal demand system |
| TJ | Tera-joules |
| TlS | Taxes less subsidies |
| TTM | Transport and trade margins |
| VA | Value added |
| WIOD | World input-output database |
| WIOT | World input-output tables |
| WS | Wage settings |

## Table of Contents

# 1. Introduction: an overview of the model

This technical report illustrates the third version of the FIDELIO (Fully Interregional Dynamic Econometric Long-term Input-Output) model. FIDELIO is a multi-regional model that has several similarities with Computable General Equilibrium (CGE) model. Compared to neoclassical CGE models — which assume that the perfect flexibility of prices and quantities ensures the full use of the factors of production at all times — FIDELIO integrates some new-Keynesian features: consumption adjusts slowly to its optimal level according to an error correction model and wages do not clear the labour market. The assumptions that prices do not clear the markets and market "imperfections" exist generate the dynamics of the model[1] that is solved sequentially (recursive dynamic). In addition, FIDELIO is an econometric model since the calibration of most of the behavioural parameters of the model (dynamic adjustment lags of prices and quantities, and elasticities) is based on econometric estimations.

With respect to the geographical coverage, FIDELIO is a multi-regional input-output model including 35 regions (the 28 Member States plus Brazil, China, India, Japan, Russia, Turkey and the United States), each of them disaggregated in 56 industries and products. The main bulk of the data used in the model comes from the international supply and use tables of the World Input-Output database (WIOD) (2016 release, the data refer to 2010). Additional information required is taken from CEDEFOP, Eurostat data, OECD data, the POLES model, UNECE data, World Bank data, and data from National Statistical Institutes of Belgium, China, Czech Republic, Hungary, India, Slovakia, Turkey, and the United Kingdom.

As a CGE model, in FIDELIO total supply equals total demand. Products flow among four main actors, each of them constituting a block in the model: firms, households, the government, and foreign countries — through international trade. Firms produce total supply. Total demand has seven components: demand for intermediate inputs, investment demand, changes in inventories, household consumption, consumption of non-profit institutions serving households (NPISH), government consumption, and demand from abroad. To these four main blocks, the model adds a capital block and a labour block to describe the markets of primary inputs. Finally, an energy block describes the environmental impact of production and consumption in terms of energy use and emissions.

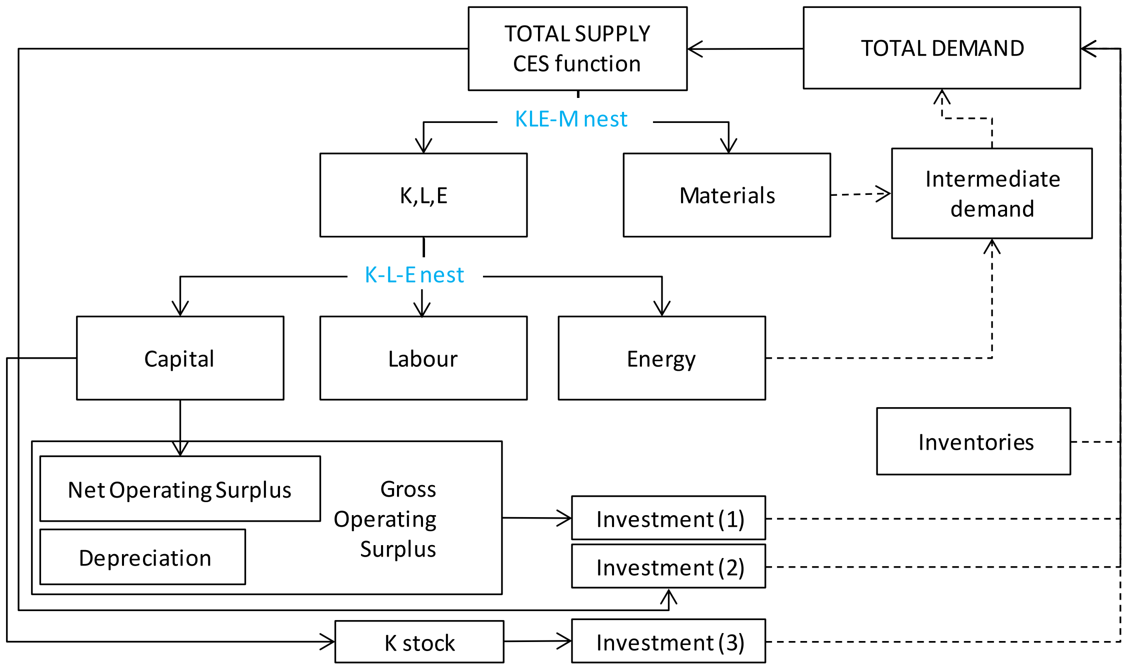
The production block is characterized by firms that adjust their production to satisfy the total demand as shown in Figure 1.[2] To produce, firms use four production factors: capital, labour, energy intermediates, and non-energy intermediates or materials. The production function that describes firms' choices is a nested CES production function with two levels. In a first level, firms choose between materials and non-materials, which is the composed bundle of factors made of capital, labour and energy inputs. Then, in a second level and depending on factor prices and substitution elasticities, firms choose across capital, labour and energy. From these production choices the first

[1] Prices and quantities might be rigid in the short run and they adjust slowly over time towards their optimal level. Being dynamic, the neo-Keynesian models are better suited to analyse medium term phenomena and the transition to the long run.

[2] The diagrams of this Section are aimed at providing a first insight of the model and do not contain all the variables of the model and the links among them.

component of the total demand originate: the demand of energy and non-energy intermediates. Other two components of final demand are related to firms' choices: investment and inventories. FIDELIO has three options to compute firms' investment, one for which relates investment to the capital stock variation. Inventories are exogenous and are assumed to shrink rapidly after the base year. From the production processes, firms pay the cost of the other factors of production (labour and capital) to households and to the government.

**Figure 1 Production block in FIDELIO**

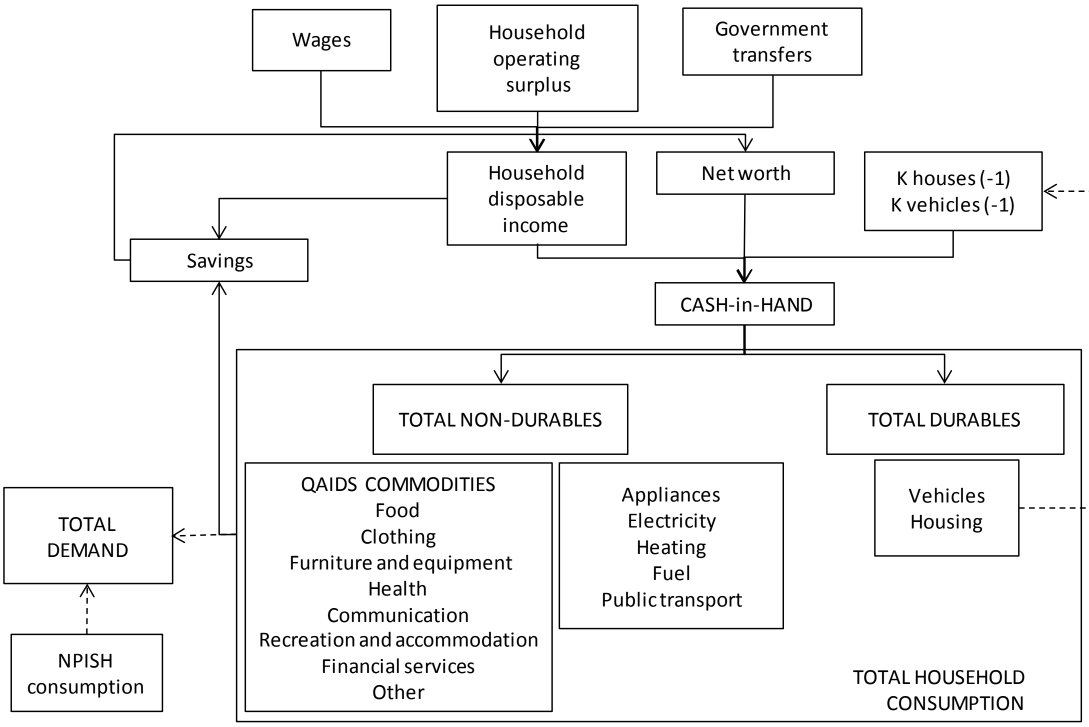



Households receive their income through wages, a share of the gross operating surplus, and the government transfers (see Figure 2).

This income, after taxes, is either used for consumption or saved. Household total consumption is another component of total demand, and depends not only on disposable income, but also on the financial assets and on the stock of durables goods (vehicles and houses) owned by households. The sum of these three components is called in FIDELIO cash-in-hand. Households consume durable products and non-durable products. Durable products are housing rents and vehicles. Non-durable products are appliances, electricity, heating, fuel for private transport, public transport, food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other. For almost all consumption categories, the demand is characterized through econometric estimations. In particular, the demand for housing, vehicles, and total non-durables is described through error correction models, slowly adjusting to its optimal level (housing rents is then a constant share of housing). Within total non-durables, the consumption of appliances, electricity, fuel, and heating is also derived econometrically. Finally, the consumption of the bundle of the remaining eight commodities is computed as a residual — as the difference between total non-durables minus appliances, electricity, fuel, heating, and public transport. Each of these commodities is then defined through a quasi- almost ideal demand system (QAIDS).

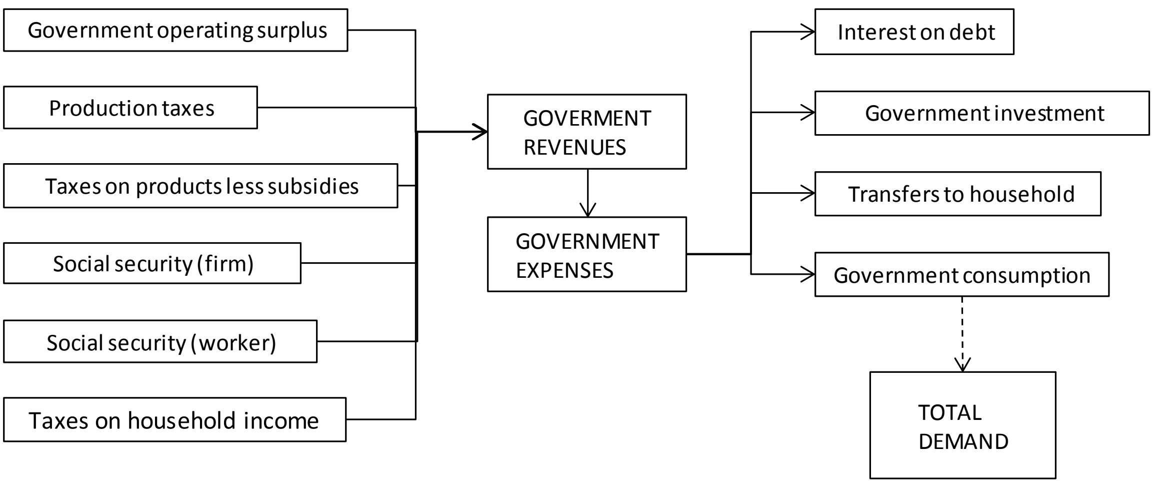
Another component of total demand is the consumption of NPISH that is treated as exogenous in FIDELIO and set accordingly to the base year data.

**Figure 2 Household block in FIDELIO**



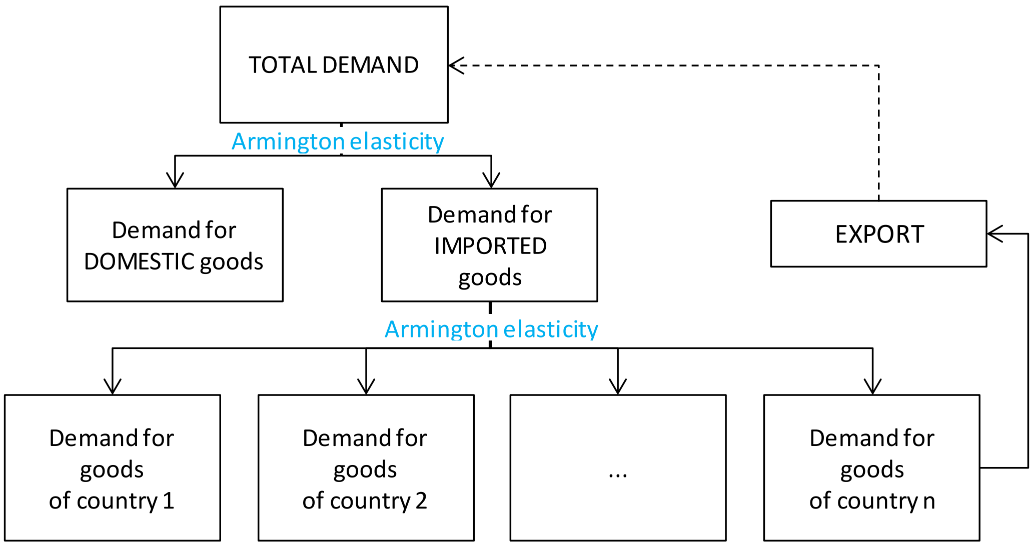

The government (see Figure 3) raises its revenue towards six main sources: operating surplus that goes to the government, production taxes, taxes less subsidies on products, social security contributions by both employers and employees, and taxes on household income. This revenue is then used to finance the government interest, the government capital formation, the government transfers to the households, and the government consumption that is another component of the total demand. The budget balance is calculated as the difference between government revenues and expenses, and it determines the variation in public debt.

**Figure 3 Government block in FIDELIO**



The last component of total demand is export (Figure 4). Bilateral export transactions are computed in FIDELIO as the mirror flow of bilateral imports. Demand for imports is modelled as a two-step procedure. First, the share of imports in total demand for each commodity is determined. Second, imports are then distributed to the country of origin. In each step Armington elasticities determine, respectively, the share of import over domestic demand and the share of each bilateral trade flow.

**Figure 4 Trade block in FIDELIO**




Looking at the labour market, the sectoral wages are derived from the so-called wages curve that describes the responsiveness of individual real wages to the changing market conditions, in particular the unemployment rate. Wages influence employment through the labour demand, while labour supply is exogenous.

Finally, the model includes also an energy block, where the monetary value of the energy consumed by firms and households is linked to energy consumption in tera-joules. This information is then used to compute emissions of carbon dioxide, methane, and nitrous oxide related to production and consumption.

The aim of this report is twofold. First, it contains all the equations of the model; second, it illustrates the characteristics of the data used by FIDELIO. The remainder of the report is organised as follows. The next Section introduces the main sets used in FIDELIO in order for the reader to know the scope of the model and to be able to better understand the dimensions of the variables appearing in the model equations. Section 3 contains all the equations of the model, and Section 4 describes the dataset.

## 2. The sets of FIDELIO

There are two sets for the countries or regions (the words "region" and "country" are used interchangeably in this document) modelled in FIDELIO: *R* (region) and *WR* (world region),[3] the only

[3] See Annex 1 for a list of the sets used in FIDELIO.

difference being that the latter also contains the rest of the world, which is not explicitly modelled in FIDELIO but exists for trade data purposes. The 35 countries modelled in FIDELIO are the 28 member states of the EU plus Brazil, China, India, Japan, Russia, Turkey and the USA.[4]

Since FIDELIO uses the data mostly taken from the WIOD project, there are 56 industries (indexed with *S*). Industries are classified under the statistical classification of economic activities NACE Rev. 2,[5] which is consistent with the International Standard Industrial Classification (ISIC) Rev. 4. Annex 2 provides a list of all FIDELIO industries. The *aU* (all Users) set contains all those industries plus the following six final demand categories (set *aC*): private household consumption, government consumption, consumption of NPISH, investment, inventories and exports.

In the model, 56 products (including services) are produced (set *G*), classified using the 2008 Classification of Products by Activity (CPA). Annex 3 provides a list of all FIDELIO CPA products. For modelling purposes, such products can be divided into two different subsets:

- Energy (*eG*) and non-energy products (*neG*),
- Services used in international trade and transport (*TIRS*) and the rest of the products (*nTIR*).

The private consumption categories, corresponding to the set *CPC,* differ from the CPA categories, as they are based on the COICOP classification[6] and then bridged to the NACE Rev. 2 categories within the model according to bridge matrices calibrated on the base year (2010) data. The *CPC* set contains the following items: rents, vehicles, appliances, electricity, heating, fuel for private transport, public transport, and eight items that in the model are treated within a QAIDS. Collectively, these eight items are grouped under the *QC* set (standing for QAIDS Commodities) and are: food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other. The three energy goods electricity, heating, and fuel for private transport are grouped under the *CPEn* set (standing for private consumption of energy). Annex 4 provides a list of the FIDELIO consumption products and the corresponding COICOP goods.

There are five components of value added (VA) in the *VAC* (value added components) set: wages, social security contributions, production taxes, depreciation, and operating surplus. As for the labour market, there are three skill levels (low, medium, and high). The labour skills (*LS)* set contains those three plus the "all" category, and the *LSca* (ca standing for calculations) only contains the three skill levels.

In the energy block of the model three sets are used: *EnC* (that stands for energy carriers and includes coal, oil, gas, renewables, and electricity and heating), *EnC_calc* (the previous one not including the total), and *EnCd* (detailed energy carriers) for all the eleven energy carriers present in the data (diesel, gasoline, jet fuel, other gas, waste, coal/coke/crude, fuel oil, liquid and biofuels, electricity for heating production, renewables/nuclear, natural gas/lpg, and other sources).

[4] These countries represent roughly the 70% of the world GDP.
[5] NACE is an acronym for "Nomenclature statistique des activités économiques dans la Communauté européenne".
[6] Classification of Individual Consumption According to Purpose.

# 3. The equations of FIDELIO

FIDELIO is a demand-driven model, in the tradition of the input-output (IO) framework, and it seems appropriate to start from the equation[7] for total demand for domestically produced goods by region and good: [8]

$$GDtot(R,G) = \sum^{aU} GD\_BP(R,G,aU) \tag{1}$$

where $GDtot$ is the total demand of domestically produced goods,[9] defined over region and good, and it is computed as the sum over all users of the demand for domestically produced goods by region, good and user, $GD\_BP$ , which in turn is defined as follows:

$$GD\_BP(R,G,aU) = G\_BP(R,G,aU) - M(R,G,aU) \tag{2}$$

$G\_BP$ is total demand in basic prices (BP) and $M$ represents imports in cost-insurance-freight (CIF) prices. Leaving aside the definition of imports for the moment (introduced in Subsection 3.4), total demand in BP is defined as follows:

$$G\_BP(R,G,aU) = G\_PP(R,G,aU) - TlS(R,G,aU) + TTMrec(R,G,aU) - TTMpaid(R,G,aU) \tag{3}$$

where $G\_PP$ is the demand in purchaser prices (PP), $TlS$ is taxes less subsidies (TlS), $TTMrec$ is trade and transport margins (TTM) received, and $TTMpaid$ is TTM paid (see Subsection 3.5 for more details on this). The total demand is composed by different parts, described in other Subsections of Section 3: intermediate demand of industries (3.1), final demand of households and NPISH (3.2), government consumption (3.3), investment and inventories (3.1), and exports (3.4).

From total demand for domestically produced goods $GDtot$, sectoral output $Q$ is derived using the market shares $MktShares_{2010}^{make}$ that is the industry shares in output of any good:

$$Q(R,S) = \sum^{G} \left( MktShares_{2010}^{make}(R,G,S) \times GDtot(R,G) \right) \tag{4}$$

The market shares are calibrated on the base year IO make (supply) table as follows:

$$MktShares_{2010}^{make}(R,G,S) = \frac{IO\_Make_{2010}(R,G,S)}{\sum^{S} IO\_Make_{2010}(R,G,S)} \tag{5}$$

Where $IO\_Make_{2010}(R,G,S)$ is the data obtained from the make matrix for 2010.[10]

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[7] As explained in the introduction, FIDELIO is a recursive dynamic model solved sequentially every year. For simplicity, in the equations of this manual we omit the time index whenever the variables refer the current year.

[8] Note that flows refer to nominal flows (monetary transactions), and not real flows (quantities).

[9] Whenever a new variable is introduced in the manual, it is followed by its definition. Anyway, since not all variables are defined after every equations (but only the variable not already defined before), and in order to ease the reading, Annex 5 and 6 provide a complete list of endogenous and exogenous variables, respectively, and their definition.

[10] Annex 7 provides a list of the base year data used for calibrating some of the FIDELIO parameters, Annex 8 provides a list of the calibrated parameters, Annex 9 provides a list of the parameters econometrically estimated, while Annex 10 provides a list of the parameters whose values have been taken from the literature.

Table 1 shows the Austrian sectoral market shares of the first four commodities as a mean to quickly illustrate the data used in equation (5).[11]

**Table 1 Austrian market shares for the first four products**

| R | G | S | $MktShares_{2010}^{make}$ |
|---|---|---|---|
| AUT | CPA_A01 | A01 | 1.000 |
| AUT | CPA_A02 | A02 | 1.000 |
| AUT | CPA_A03 | A03 | 1.000 |
| AUT | CPA_B | A01 | 0.002 |
| AUT | CPA_B | B | 0.898 |
| AUT | CPA_B | C20 | 0.001 |
| AUT | CPA_B | C23 | 0.058 |
| AUT | CPA_B | C24 | 0.000 |
| AUT | CPA_B | D35 | 0.001 |
| AUT | CPA_B | F | 0.028 |
| AUT | CPA_B | G46 | 0.002 |
| AUT | CPA_B | G47 | 0.002 |
| AUT | CPA_B | H49 | 0.006 |
| AUT | CPA_B | H52 | 0.002 |

## 3.1 The production block

To introduce the production block, Subsection 3.1.1 describes the production function used in FIDELIO, while Subsection 3.1.2 focuses on how investment, capital stock, and inventories are characterized in FIDELIO.

### 3.1.1 The production function

FIDELIO uses a nested CES production function with four factors of production: capital, labour, energy intermediates (CPA_B, CPA_C19, and CPA_D35) and materials, where materials equal the non-energy intermediates.[12]

The nested CES production function exhibits two levels, as shown in Figure 1. At the first level, firms minimize costs choosing between materials and an aggregate consisting in capital, labour, and energy bundle (KLE). At the second level, the aggregate KLE is further split into its three components.

The equations of the production function are now introduced in the following order. First, we show how the shares of factors of production are determined in FIDELIO. Second, we explain how the shares' parameters of the production function are calibrated using the base year data. Third, we describe how the shares are then used to find the demands of factors.

Looking at the shares of factors of production, let's first introduce the shares of the first level, that is the share of the bundle KLE and the materials share.

[11] Annex 11 provides a list of the abbreviations used to indicate the FIDELIO countries.
[12] Non-energy intermediates include all CPAs not included in energy intermediates.

The KLE share $KLE\_Q$ is determined as follows:

$$KLE\_Q(R,S) = \alpha^{KLE}(R,S) \times \left(\frac{P\_KLE(R,S)}{PQ(R,S)}\right)^{1-\sigma^{KLE\_M}(R,S)} \tag{6}$$

Where $\alpha^{KLE}$[13] is the share parameter for the KLE bundle within the first (or KLE-M) nest, $P\_KLE$ is the price of combined capital, energy, and labour inputs, $PQ$ is the output price, and $\sigma^{KLE\_M}$ is substitution elasticity between KLE and M elements.

Similarly, the materials share in the first nest level $SM\_Q$ is given by:

$$SM\_Q(R,S) = \alpha^{M}(R,S) \times \left(\frac{P\_SM(R,S)}{PQ(R,S)}\right)^{1-\sigma^{KLE\_M}(R,S)} \tag{7}$$

$\alpha^{M}$ being the share parameter for materials within KLE-M nest, and $P\_SM$ the price of the materials.

The parameters $\alpha^{KLE}$ and $\alpha^{M}$ are calibrated to fit the base year data as described later. By default, the substitution elasticity $\sigma^{KLE\_M}$ of the first nest is set equal to 0, assuming no substitution between the KLE bundle and materials. This is a standard assumption in the modelling literature generally supported by empirical evidences (e.g. GTAP model) since intermediary material consumption are products incorporated or destroyed during the production process. They are therefore not substitutable to the other inputs.

Once the KLE share and the materials share are determined, they are used to determine the shares of capital, energy, and labour in the second nest (or K-L-E) level.

In particular, starting from capital, the capital share in the second nest level is:

$$SC\_Q(R,S) = KLE\_Q(R,S) \times \alpha^{C}(R,S) \times \left(\frac{PInputs(R,S,"Capital")}{P\_KLE(R,S) \times fprod(R,S,"Capital")}\right)^{1-\sigma^{K\_L\_E}(R,S)} \tag{8}$$

$\alpha^{C}$ is the relative share parameter of capital, and it is calibrated to fit the base year data as described below. $PInputs(R,S,"Capital")$ is the price of capital. $fprod(R,S,"Capital")$ is a parameter of capital productivity, and by default is set equal to one. Finally, $\sigma^{K\_L\_E}$ is the substitution elasticity between capital, labour, and energy. We set its value equal to 0.95 which is in line with the calibration of other CGE models and econometric results. In the empirical literature, there is a large heterogeneity across estimations that comes from several factors: the production function specification estimated (e.g. translog versus nested CES, structure of the nest), the estimation method, the countries and/or industries under consideration, the data period. Looking at the meta-analysis performed by Koetse et al. (2008), about 80% of the studies retained (all of them carried out before 2000 and most of them estimating a translog function) find that the elasticity of substitution between capital and energy is below one. The survey of Okawa and Ban (2008) reaches a similar conclusion for the elasticity of substitution between capital, energy and labour although they point out that the Cobb–Douglas hypothesis (unit elasticity) is not rejected in certain studies.

[13] We define $\alpha^{KLE}$ and $\alpha^{M}$ as share parameters, because they are the parameters that define the share of the KLE bundle and the share of materials per unit of output. On the contrary, we define the three parameters $\alpha^{C}$, $\alpha^{L}$ and $\alpha^{E}$ as relative share parameters because they refer to the weight of each factor relative to the bundle KLE (in fact, their sum is equal to 1).

Similarly, the equation that determines the labour share is:

$$SL\_Q(R,S) = KLE\_Q(R,S) \times \alpha^{L}(R,S) \times \left(\frac{PInputs(R,S,"L")}{P\_KLE(R,S) \times fprod(R,S,"L")}\right)^{1-\sigma^{K\_L\_E}(R,S)} \quad (9)$$

where $\alpha^{L}$ is the relative share of labour calibrated to fit the base year data, $PInputs(R,S,"L")$ is the price of labour, and $fprod(R,S,"L")$ is a parameter of labour productivity, set by default equal to one.

Also the energy share is determined as:

$$SE\_Q(R,S) = KLE\_Q(R,S) \times \alpha^{E}(R,S) \times \left(\frac{PInputs(R,S,"E")}{P\_KLE(R,S) \times fprod(R,S,"E")}\right)^{1-\sigma^{K\_L\_E}(R,S)} \quad (10)$$

being $\alpha^{E}$ the relative share of energy calibrated to fit the base year data, $PInputs(R,S,"E")$ is the price of energy, and $fprod(R,S,"E")$ the parameter of energy productivity, set by default equal to one.

As previously suggested, all parameters $\alpha$ in (6) to (10) that represent the relative shares of the factors of production are calibrated over the base year data. FIDELIO first computes the share of total intermediate inputs over the sectoral output as:

$$S\_Q_{2010}(R,S) = \frac{\sum^{G} IO\_Use\_PP_{2010}(R,G,S)}{Q_{2010}(R,S)}, \quad (11)$$

where $IO\_Use_{PP_{2010}}$ is the use matrix for 2010, and $Q_{2010}(R,S) = \sum^{G} IO\_Make_{2010}(R,S,G)$.

Then, the share of energy intermediate $SE\_Q_{2010}$ and the share of materials $SM\_Q_{2010}$ are calculated as follow:

$$SE\_Q_{2010}(R,S) = \frac{\sum^{eG} IO\_Use\_PP_{2010}(R,eG,S)}{Q_{2010}(R,S)} \quad (12)$$

$$SM\_Q_{2010}(R,S) = S\_Q_{2010}(R,S) - SE\_Q_{2010}(R,S) \quad (13)$$

The labour share is calculated starting from VA data:

$$SL\_Q_{2010}(R,S) = \frac{[VAblocks_{2010}(R,S,\text{"Wages"}) + VAblocks_{2010}(R,S,"SocSec")]}{Q_{2010}(R,S)} \quad (14)$$

$VAblocks_{2010}(R,S,$"Wages"$)$ being the wages component in VA from 2010 data, and $VAblocks_{2010}(R,S,$"SocSec"$)$ data on social security contributions.

Lastly, capital in FIDELIO is defined as a residual: VA minus labour compensation (including gross operating surplus, production taxes minus subsidies, and depreciation). Its share over output *Q* is:

$$SC\_Q_{2010}(R,S) = 1 - S\_Q_{2010}(R,S) - SL\_Q_{2010}(R,S) \quad (15)$$

From these shares, the relative share parameters for the KLE bundle ($\alpha^{KLE}$ ) and for materials ($\alpha^{M}$) within the first nest are:

$$\alpha^{KLE}(R,S) = SC\_Q_{2010}(R,S) + SL\_Q_{2010}(R,S) + SE\_Q_{2010}(R,S) \quad (16)$$

$$\alpha^{M}(R,S) = 1 - \alpha^{KLE}\,(R,S) \tag{17}$$

The relative share parameters for capital, labour, and energy within the second nest are, respectively:

$$\alpha^{C}(R,S) = \frac{SC\_Q_{2010}(R,S)}{\alpha^{KLE}(R,S)} \tag{18}$$

$$\alpha^{L}(R,S) = \frac{SL\_Q_{2010}(R,S)}{\alpha^{KLE}(R,S)} \tag{19}$$

$$\alpha^{E}(R,S) = \frac{SE\_Q_{2010}(R,S)}{\alpha^{KLE}(R,S)} \tag{20}$$

As an example, Table 2 illustrates the factors shares from the base year data for the first eight industries with Austrian data and the relative shares.

**Table 2 Austrian factors shares for the first eight products**

| R | S | $SM\_Q_{2010}$ $\alpha^{M}$ | $SC\_Q_{2010}$ | $SL\_Q_{2010}$ | $SE\_Q_{2010}$ | $\alpha^{KLE}$ | $\alpha^{C}$ | $\alpha^{L}$ | $\alpha^{E}$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| AUT | A01 | 0.514 | 0.370 | 0.047 | 0.069 | 0.486 | 0.761 | 0.096 | 0.143 |
| AUT | A02 | 0.492 | 0.389 | 0.093 | 0.026 | 0.508 | 0.765 | 0.183 | 0.052 |
| AUT | A03 | 0.596 | 0.264 | 0.059 | 0.081 | 0.404 | 0.654 | 0.146 | 0.200 |
| AUT | B | 0.280 | 0.373 | 0.142 | 0.205 | 0.720 | 0.518 | 0.197 | 0.285 |
| AUT | C10-C12 | 0.678 | 0.148 | 0.151 | 0.024 | 0.322 | 0.459 | 0.468 | 0.073 |
| AUT | C13-C15 | 0.612 | 0.155 | 0.213 | 0.020 | 0.388 | 0.399 | 0.548 | 0.052 |
| AUT | C16 | 0.689 | 0.128 | 0.151 | 0.032 | 0.311 | 0.411 | 0.486 | 0.103 |
| AUT | C17 | 0.629 | 0.140 | 0.148 | 0.083 | 0.371 | 0.377 | 0.399 | 0.225 |

Note: Columns are related in the following ways: (7) =(4)+(5)+(6); (3)+(7)=1; (8)+(9)+(10)=1.

Once the shares of the factors of production are determined, they are then used to find the demand of materials, capital, labour, and energy, via simple multiplication by output:

$$Materials(R,S) = SM\_Q(R,S) \times Q(R,S) \tag{21}$$

$$Capital(R,S) = SC\_Q(R,S) \times Q(R,S) \tag{22}$$

$$Labour(R,S) = SL\_Q(R,S) \times Q(R,S) \tag{23}$$

$$Energy(R,S) = SE\_Q(R,S) \times Q(R,S), \tag{24}$$

The demand for labour is then used to determine VA components related to labour, that is wages ($VAblocks(R,S,\text{"Wages"})$) and social security contributions ($VAblocks(R,S,\text{"SocSec"})$), by multiplying the labour demand by the relative share of wages and social security contributions from 2010 data:

$$VAblocks(R,S,\text{"Wages"}) = Labour(R,S) \times \frac{VAblocks_{2010}(R,S,\text{"}Wages\text{"})}{VAblocks_{2010}(R,S,\text{"}Wages\text{"})+VAblocks_{2010}(R,S,\text{"}SocSec\text{"})} \tag{25}$$

$$VAblocks(R,S,\text{"SocSec"}) = Labour(R,S) - VAblocks(R,S,\text{"Wages"}) \tag{26}$$

The rest of the VA components are also found via multiplication by output. Production taxes and depreciation are defined as:

$$VAblocks(R,S,"ProdTax") = Q(R,S) \times \frac{VAblocks_{2010}(R,S,"ProdTax")}{Q_{2010}(R,S)}, \tag{27}$$

$$VAblocks(R,S,"Depr") = Q(R,S) \times \frac{VAblocks_{2010}(R,S,"Depr")}{Q_{2010}(R,S)}, \tag{28}$$

where $VAblocks_{2010}(R,S,"ProdTax")$ are the sectoral production taxes in 2010 and $VAblocks_{2010}(R,S,"Depr")$ the sectoral depreciation in 2010.

Finally, the last component of VA is the operating surplus that is calculated with the following equation:

$$\begin{gathered} VAblocks(R,S,"OpSur") = Capital(R,S) - \\ -VAblocks(R,S,"ProdTax") - VAblocks(R,S,"Depr") \end{gathered} \tag{29}$$

Therefore, total VA is the sum of all its components:

$$\begin{gathered} VA(R,S) = VAblocks(R,S,"Wages") + VAblocks(R,S,"SocSec") + \\ +VAblocks(R,S,"ProdTax") + VAblocks(R,S,"Depr") + VAblocks(R,S,"OpSur") \end{gathered} \tag{30}$$

Finally, the demand for non-energy intermediates (or materials) and for energy intermediates are used to compute the commodity demand in PP for intermediate inputs in each industry as follows:

$$\begin{gathered} G\_PP(R,G,S) = Materials(R,S) \times \frac{IO\_USE\_PP_{2010}(R,neG,S)}{\sum^{neG} IO\_USE\_PP_{2010}(R,neG,S)} + \\ +Energy(R,S) \times \frac{IO\_USE\_PP_{2010}(R,eG,S)}{\sum^{eG} IO\_USE\_PP_{2010}(R,eG,S)} \end{gathered} \tag{31}$$

where the industry-good structures come from the base year data.

### 3.1.2 Investment, the stock of capital, and inventories

At the moment, in FIDELIO there are three alternative options to generate investment. As a first option, investment can be computed as a constant share of the gross operating surplus, which is the sum of operating surplus plus depreciation, as follows:

$$I\_PP\_GOP(R,S) = [VAblocks(R,S,\text{"OpSur"}) + VAblocks(R,S,\text{"Depr"})] \times IO\_I\_GOP_{2010}(R,S) \tag{32}$$

where $IO\_I\_GOP_{2010}$ is the proportion of investment over gross operating surplus in the base year data.

As a second option, the model derives sectoral investment as a share of the sectoral production in the following way:

$$I\_PP\_Q(R,S) = Q(R,S) \times IO\_I\_Q_{2010}(R,S), \tag{33}$$

where $IO\_I\_Q_{2010}$ *Q* is the proportion of investment over output in the base year data.

Finally, the third option relates investment to capital stock that is defined as follows:

$$KStock(R,S) = \left(\frac{Capital(R,S) - VAblocks(R,S,"ProdTax")}{PInputs(R,S,"Capital")} \times \frac{1}{KRemuner}\right), \quad (34)$$

where $PInputs(R, S, "capital")$ is the capital price and $KRemuner$ is a parameter that represents the remuneration of capital and is set equal to 0.03 as in EXIOMOD.[14]

Then, investment is calculated as:

$$I\_PP\_KStock(R,S) = KStock(R,S) - KStock_{t-1}(R,S) \times (1 - DeprRate), \quad (35)$$

where DeprRate represents the depreciation rate of capital stock and by default is equal to 0.05.[15]

The investment at a industry level is finally aggregated into the investment demand:

$$G\_PP(R, G, "Inv") = \sum^{S} I\_PP(R,S) \times IStruct_{2010}(R, G, S) \quad (36)$$

where $I\_PP$ can result from equation (32), (33),or (35). *$IStruct_{2010}$* is the commodity investment structure by industry: $IStruct_{2010}(R, G, S) = \frac{InvMatrix_{2010}(R,G,S)}{\sum^{G} InvMatrix_{2010}(R,G,S)}$, where $InvMatrix_{2010}$ is the matrix of investment data by industry and by good.

In FIDELIO, inventories are exogenous and are assumed to shrink rapidly after the base year. The equation governing inventories is the following:

$$G\_PP(R, G, "Inventory") = Inventory\_PP_{2010}(R, G) \times 0.9^{i-1} \quad (37)$$

where $Inventory\_PP_{2010}$ is the commodity demand for inventories in the base year data and *i* starts from 1 in the first year of the FIDELIO simulation and increases every year of the simulation — which typically goes from 2010 to 2050.

## 3.2 The household block

This Subsection describes how households receive their income through different sources (Subsection 3.2.1) and how they use it to consume durable and non-durable products (Subsection 3.2.2 and 3.2.3, respectively). Finally, Subsection 3.2.4 introduces the NPISH consumption.

### 3.2.1 Household income and wealth

The main concept of the household block is cash-in-hands, *CashHH*. This is defined as disposable income ($YD$), plus financial assets ($NetWorthHH$) and vehicles and houses stocks ($KVehicles$ and $KHous$), the idea being that households not only consume out of income, but also out of their assets (the latter is commonly known as the wealth effect in the literature on consumption and savings).

[14] http://owsgip.itc.utwente.nl/projects/complex/index.php/2-uncategorised/23-exiomod

[15] At the moment, this third method to compute investment is still a working process, so only the other two methods are used in FIDELIO.

$$CashHH(R) = YD(R) + NetWorthHH(R) + \\ + KVehicles_{t-1}(R) \times (1 - \delta^{veh}) + KHous_{t-1}(R) \times (1 - \delta^{hous}) \tag{38}$$

where the depreciation rate for vehicles $\delta^{veh}$ is by default 0.08 and the depreciation rate for houses $\delta^{hous}$ 0.015 (see Wilhelmsson, 2008).

Households accumulate assets and liabilities which results in a certain net wealth ($NetWorthHH$). Equation (39) explains how it evolves:

$$NetWorthHH(R) = NetWorthHH_{t-1}(R) + SavHH(R) + \\ -(1 - \theta) \times [CPgfcf\_housing(R) + CPCom(R, "Veh")] \tag{39}$$

Household net wealth depends on past net wealth ($NetWorthHH_{t-1}$), savings ($SavHH$), and new debt represented by the proportion of expenditure in housing ($CPgfcf\_housing$) and in vehicles $CPCom(R, "Veh")$ that can be financed with debt. The parameter $\theta$ in equation (39) represents in fact collaterals for household durables (and is set equal to 0.37).

Equation (40) defines household savings as the difference between disposable income and total households consumption $CPComm(R, "Tot")$ .

$$SavHH(R) = YD(R) - CPComm(R, "Tot") \tag{40}$$

Disposable income is an important component of cash-in-hands, and it is defined as follows:

$$YD(R) = \sum^{S} VAblocks(R, S, "Wages") - YDSSec^{employee}(R) - YDTaxesHH(R) + \\ + YDOpSurHH(R) + YDTran(R) + YDOtherTran(R) \tag{41}$$

where $YDSSec^{employee}$ is social security contributions paid by workers, $YDTaxesHH$ represents taxes paid by households to the government, $YDOpSurHH$ is the share of gross operating surplus going to households, and $YDTran$ and $YDOtherTran$ are, respectively, transfers paid by the government to households and other transfers. The equations below illustrate how these different components of disposable income are modelled.

Social security contributions paid by workers are proportional to the labour demand:

$$YDSSec^{employee}(R) = \sum^{S} Labour(R, S) \times \frac{YDSSec^{employee}_{2010}(R)}{\sum^{S} Labour_{2010}(R, S)} \tag{42}$$

where $YDSSec^{employee}_{2010}$ is the base year social security contributions paid by workers from National Account data, and $Labour_{2010}$ the labour cost in 2010 data.

Taxes paid by households to the government are:

$$YDTaxesHH(R) = IO\_Tax\_Inc_{2010}(R) \times \\ \times \left[\sum^{S} VAblocks(R, S, "Wages") - YDSSec^{employee}(R) + YDOpSurHH(R)\right] \tag{43}$$

$IO\_Tax\_Inc_{2010}$ being the 2010 ratio of household income taxes over income as calculated in the square brackets of equation (43).

Household operating surplus is calculated as a fixed share of the gross operating surplus based on the share in the base year data $IO\_HHShOp_{2010}$:

$$
\begin{aligned}
YDOpSurHH(R) = \sum^{S} \left(VAblocks(R,S,\text{"}Depr\text{"}) + VAblocks(R,S,\text{"}OpSur\text{"})\right) * \\
* IO\_HHShOp_{2010}(R)
\end{aligned}
\tag{44}
$$

being $IO\_HHShOp_{2010}$ the share of operating surplus that goes to households in the base year.

Finally, $YDTran$ and $YDOtherTran$ are exogenous and set to be equal to their 2010 values.

### 3.2.2 Consumption of durables

Households use their income and wealth to finance consumption. FIDELIO features a rich consumption block. The equations that rule the household consumption are mostly specified using the error correction model.[16] Error correction specifications are chosen so to acknowledge the importance of past consumption in shaping actual and future consumption. The model distinguishes between consumption of durable and non-durable commodities.

There are two categories of durables in FIDELIO: houses and vehicles. Household expenditures in houses depend on previous housing consumption, cash on hand, and the collaterals for household durables, according to the following equation:

$$
\begin{aligned}
ln\left(CPgfcf\_housing(R)\right) = ln\left(CPgfcf\_housing_{t-1}(R)\right) + \\
+c_2^{hou}\left[ln\left(CashHH(R)\right) - ln\left(CashHH_{t-1}(R)\right)\right] + c_3^{hou}\left[\theta(R) - \theta_{t-1}(R)\right] + \\
+c_4^{hou}\left[ln\left(CPgfcf\_housing_{t-1}(R)\right) + c_5^{hou}\,ln\left(CashHH_{t-1}(R)\right) + c_6^{hou}\,ln\left(CashHH_{t-1}(R)\right) ln\left(\frac{KHous_{t-2}(R)}{NumberHH(R)}\right) + c_7^{hou}\theta_{t-1}(R)\right]
\end{aligned}
\tag{45}
$$

where an explanatory variable in the error correction term is the stock of housing per household, being $NumberHH$ the number of households. The parameter $\theta$ stands for the part of investment in durables that cannot be financed via debt, allowing for the analysis of the effects of credit constraints. The $c$ parameters are not country-specific and come from panel estimates.[17] Their values are the following: $c_2^{hou} = 0.90$, $c_3^{hou} = -0.35$, $c_4^{hou} = -0.18$, $c_5^{hou} = -1.42$, $c_6^{hou} = 0.04$, and $c_7^{hou} = 0.12$.

The equation for expenditure in vehicles is the following:

$$
\begin{aligned}
ln\left(CPComm(R,\text{"}Veh\text{"})\right) = ln\left(CPComm_{t-1}(R,\text{"}Veh\text{"})\right) + \\
+c_2^{veh}\left[ln\left(CashHH(R)\right) - ln\left(CashHH_{t-1}(R)\right)\right] + c_3^{veh}\left[\theta(R) - \theta_{t-1}(R)\right] + \\
+c_4^{veh}\left[ln\left(PComm(R,\text{"}Veh\text{"})\right) - ln\left(PComm_{t-1}(R,\text{"}Veh\text{"})\right)\right] + c_5^{veh}\left[ln\left(CPComm_{t-1}(R,\text{"}Veh\text{"})\right) + c_6^{veh}\,ln\left(CashHH_{t-1}(R)\right)\right. \\
\left.+c_7^{hou}\,ln\left(CashHH_{t-1}(R)\right) ln\left(\frac{KVeh_{t-2}(R)}{NumberHH(R)}\right) + c_8^{hou}\theta_{t-1}(R) + c_9^{hou}\,ln\left(PComm_{t-1}(R,\text{"}Veh\text{"})\right)\right]
\end{aligned}
\tag{46}
$$

where $PComm(R,\text{"}Veh\text{"})$ is the price of vehicles. In this case, the parameters assume the following values (estimated using panel data): $c_2^{veh} = 0.43$ , $c_3^{veh} = 0.02$ , $c_4^{veh} = 0.91$ , $c_5^{veh} = -0.36$ , $c_6^{veh} = -0.81$, $c_7^{veh} = 0.02$, $c_8^{veh} = 0.02$ and $c_9^{veh} = -0.86$.

---

[16] The most part of the values of the parameters in the following equation have been estimated using panel estimates.

[17] Most coefficients governing household consumption are econometrically estimated. See Annex 9 for a list of the coefficients that have been estimated.

And now for the rest of the equations of the household block.

The stocks of houses and vehicles change according to the following relationships:

$$KHous(R) = \left(1 - \delta^{hous}\right) \times KHous_{t-1}(R) + CPgfcf\_housing(R) \quad (47)$$

$$KVehicles(R) = \left(1 - \delta^{vehicles}\right) \times KVehicles_{t-1}(R) + CPComm(R, "Veh") \quad (48)$$

The actual durable consumption related to houses takes the form of rents (corresponding in the base year data to the sum of imputed rents, actual rents, expenditures for the maintenance of the dwelling, and water expenditure) which are derived from the housing stock:

$$CPComm(R, "Rents") = KHous_{t-1}(R) \times Rent\_Houses_{2010}(R) \quad (49)$$

where $Rent\_Houses_{2010}$ is the ratio of rents over housing stock in the base year.

Total consumption of durables is then calculated as follows:

$$CPComm(R, "TotDur") = CPComm(R, "Rents") + CPComm(R, "Veh") \quad (50)$$

### 3.2.3 Consumption of non-durables

Total consumption of non-durables, $CPComm(R, "NonDur")$, is derived as follows:

$$\begin{aligned} ln\left(CPComm(R, "NonDur")\right) &= ln\left(CPComm_{t-1}(R, "NonDur")\right) + \\ &+ c_2^{nond}\left[ln\left(CashHH(R)\right) - ln\left(CashHH_{t-1}(R)\right)\right] + c_3^{nond}\left[ln\left(CPComm_{t-1}(R, "NonDur")\right) + \right. \\ &\left. + c_4^{nond}\, ln\left(CashHH_{t-1}(R)\right) + c_5^{nond} \times \theta_{t-1}(R) \times ln(CPgfcf\_housing_{t-1}(R) + CPComm_{t-1}(R, "Veh"))\right] \end{aligned} \quad (51)$$

In this case, the parameters assume the following values (estimated using panel data): $c_2^{nond} = 0.23$, $c_3^{nond} = -0.14$, $c_4^{nond} = -0.82$ and $c_5^{nond} = 0.01$. Total consumption is simply the sum of non-durable and durable consumption.

Let us now lay out the equations related to the consumption of non-durable commodities. First of all, appliances are treated as such even though a stock of appliances also exists ($KAppl$) which depreciates at the rate of $\delta^{appl} = 0.07$. The consumption of appliances is treated differently from that of housing and vehicles for the impossibility to finance their purchases with debt. It depends on previous stock of appliances and on current appliances consumption $CPComm(R, "Appl")$.

$$KAppl(R) = CPComm(R, "Appl") + \left(1 - \delta^{appl}\right) \times KAppl_{t-1}(R) \quad (52)$$

The consumption of appliances works as follows:

$$ln\left(CPComm(R, "Appl")\right) = c_2^{appl} \times ln\left(PAppl(R)\right) + c_3^{appl} \times ln\left(CPComm(R, "NonDur")\right) \quad (53)$$

where $PAppl$ is the price of appliances, $c_2^{appl} = 0.54$, and $c_3^{appl} = 0.68$ (estimated using panel data).

As for the rest of non-durable goods and services, let us differentiate between and energy block and a non-energy one. The former includes consumption of electricity, fuel for private transport, heating fuel, and public transportation services. The relevant equations for electricity consumption and for fuel consumption are as follows.

$$\begin{gathered} ln\big(CPComm(R,"Elec")\big) = ln\big(KAppl\ (R)\big) + \\ +c_2^{el} \times ln(PElec(R) \times Eff\_Appl(R)) + c_3^{el} \times ln\left(\frac{CPComm_{t-1}(R,"Elec")}{KAppl_{t-1}(R)}\right) + c_4^{el} \times ln(HeatDDay_{2010}(R)) \end{gathered} \tag{54}$$

$$\begin{gathered} ln\big(CPComm(R,"Fuel")\big) = ln\big(KVehicles(R)\big) + \\ +c_2^{fuel} \times ln(PFuel(R) \times Eff\_Veh(R)) + c_3^{fuel} \times ln\left(\frac{CPComm_{t-1}(R,"Veh")}{KVehicles_{t-1}(R)}\right) + c_4^{fuel} \times ln(VehPop_{2010}(R)) \end{gathered} \tag{55}$$

Where $PElec$ is the electricity price, $PFuel$ the price of fuel; $Eff\_Appl$ and $Eff\_Veh$ are exogenous indices capturing the efficiency of appliances and vehicles, respectively; $HeatDDay_{2010}$ stands for heating degree days, a measurement designed to quantify the demand for energy needed to heat a building; $VehPop_{2010}$ is the exogenous number of vehicles divided by population[18]; $c_2^{el} = 0.21$, $c_3^{el} = 0.59$, $c_4^{el} = 0.13$, $c_2^{fuel} = 0.38$, $c_3^{fuel} = 0.69$, and $c_4^{fuel} = -0.47$ (estimated using panel data).

Heating consumption and is defined as follows:

$$\begin{gathered} ln\big(CPComm(R,"Heat")\big) = ln\big(KHous(R)\big) + \\ +c_2^{heat} \times ln(PHeat(R) \times Eff\_Heat(R)) + c_3^{heat} \times ln\left(\frac{CPComm_{t-1}(R,"Heat")}{KHous_{t-1}(R)}\right) + c_4^{heat} \times ln(HeatDDay_{2010}(R)) \end{gathered} \tag{56}$$

where $Eff\_Heat$ is an index capturing the efficiency of heating, $PHeat$ is the price of heating, $c_2^{heat} = 0.10$, $c_3^{heat} = 0.84$, and $c_4^{heat} = 0.46$.

Finally, the consumption of public transportation services is a fixed share of fuel consumption based on its share in 2010:

$$CPComm(R,"PubTran") = CPComm(R,"Fuel") \times \frac{CPComm_{2010}(R,"PubTran")}{CPComm_{2010}(R,"Fuel")} \tag{57}$$

Total expenditure on transportation services, $CPComm(R,"Tran")$, is the sum of $CPComm(R,"PubTran")$ and $CPComm(R,"Fuel")$. Total expenditure on energy services, $CPComm(R,"Energy")$, is the sum of $CPComm(R,"Tran")$, $CPComm(R,"Heat")$ and $CPComm(R,"Elec")$.

The set of non-durables consumption is completed by eight categories which work in FIDELIO within a QAIDS. The categories are the following: food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other. Total consumption of these categories is the following:

$$CPQAIDS(R) = CPComm(R,"NonDur") - CPComm(R,"Energy") - CPComm(R,"Appl") \tag{58}$$

First, the shares of the eight commodities are found as follows:

[18] Population data are taken from the UN projections, medium variant. Eurostat provides data for the number of vehicles for most of the European countries treated in FIDELIO. The average number of vehicles calculated with these data is used to fill for the countries for which no data are available, assuming that the average number of vehicles is low for Brazil, China, and India, and high for Denmark, Japan and the USA, and in the middle for Russia. See Section 4 for more details on the data.

$$QAIDSShare(R,QC) = c_1^{aids}(R,QC) \times ln\left(\frac{PComm(R,QC)}{PCP(R)}\right) + \\ + \sum^{QC} c_{QC}^{aids}(R,QC,QC) \times ln(PComm(R,QC)) \tag{59}$$

where $PComm(R,QC)$ is the price of the QAIDS products, and $PCP$ is the consumer price index.

The values of the estimated $c_1^{aids}$ and $c_{QC}^{aids}$ parameters of equation (59) for the eight commodities are country-specific, and those related to Austria are shown in Table 3 as an example.

**Table 3 Values of the $c^{aids}$ parameters for Austria**

| | $c_1$ | food | cloth | furn | health | comm | recr | fin | other |
|---|---|---|---|---|---|---|---|---|---|
| food | -0.098 | 0.281 | | | | | | | |
| cloth | 0.027 | 0.024 | 0.045 | | | | | | |
| furn | 0.038 | 0.050 | 0.007 | 0.002 | | | | | |
| health | 0.009 | 0.009 | -0.002 | 0.002 | 0.011 | | | | |
| comm | -0.014 | 0.010 | 0.002 | 0.021 | 0.001 | 0.007 | | | |
| recr | 0.054 | 0.010 | 0.050 | 0.027 | 0.044 | 0.127 | 0.139 | | |
| fin | 0.000 | 0.053 | 0.012 | 0.010 | 0.005 | -0.005 | 0.014 | 0.012 | |
| other | -0.016 | -0.437 | -0.138 | -0.119 | -0.070 | -0.163 | -0.409 | -0.100 | 1.437 |

Then, the consumption in absolute value is derived by multiplying those shares for *CPQAIDS*:

$$CPComm(R,QC) = CPQAIDS(R) \times QUAIDSShare(R,QC) \tag{60}$$

The only thing needed to get to total private consumption $G\_PP(R,G,"CP")$ by region and by good is now a matrix bridging the consumption categories (see the *CPC* set) to the 56 products of the NACE Rev. 2 classification. The bridge matrix $CPBridge_{2010}$ is computed from *CPC*-NACE Rev. 2 data on household consumption for 2010, and is used in the following equation:

$$G\_PP(R,G,"CP") = \sum^{CPC}\left(CPBridge_{2010}(R,G,CPC) \times CPComm(R,CPC)\right) \tag{61}$$

### 3.2.4 Non-profit institutions serving households

The user NPISH is treated as exogenous in FIDELIO, and set according to the base year values of the relevant VA variables:

$$NPISH(R) = \sum^{S} VA(R,S) \times \frac{\sum^{G} IO\_NPISH_{2010}(R,G)}{\sum^{S} VA_{2010}(R,S)} \tag{62}$$

Where $IO\_NPISH_{2010}$ is NPISH consumption in 2010.

The WIOD use commodity structure of 2010 $UseStruct_{2010}(R,G,"NPISH")$ is used to derive final demand by NPISH by region and good:

$$G\_PP(R,G,"NPISH") = NPISH(R) \times UseStruct_{2010}(R,G,"NPISH") \tag{63}$$

### 3.3 The government block

Governmental total revenues are equal to the sum of operating surplus that goes to the government ($GovOpSur$), TlS on products ($GovTlS$), production taxes ($GovProdTax$), social security contributions by both employers ($YDSSec^{employer}$) and employees ($YDSSec^{employee}$), and taxes on household income ($YDTaxesHH$). Governmental total revenues are therefore equal to the following:

$$GovTotRev(R) = GovOpSur(R) + GovTlS(R) + GovProdTax(R) + \\ +YDTaxesHH(R) + YDSSec^{employer}(R) + YDSSec^{employee}(R) \tag{64}$$

The operating surplus going to the government is computed as a fixed share of the total operating surplus based on the share in the base year data $IO\_GovShOp_{2010}$:

$$GovOpSur(R) = \sum^{S} [VAblocks(R,S,\text{"OpSur"}) + VAblocks(R,S,\text{"Depr"})] \times IO\_GovShOp_{2010}(R) \tag{65}$$

The government revenue from TlS is the sum over all users and products of TlS:

$$GovTlS(R) = \sum^{aU}\sum^{G} TlS(R,G,aU) \tag{66}$$

where TlS are defined as:

$$TlS(R,G,aU) = G\_PP(R,G,aU) \times \frac{IO\_CommTlS_{2010}(R,G,aU)}{1+IO\_CommTlS_{2010}(R,G,aU)} \tag{67}$$

where $IO\_CommTlS_{2010}$ is the proportion of TlS over the use value in basic prices plus trade and transport margins in the base year.

Another government revenue is the sum of production taxes:

$$GovProdTax(R) = \sum^{S} VAblocks(R,S,\text{"}ProdTax\text{"}) \tag{68}$$

where production taxes are defined as a share of output

$$VAblocks(R,S,\text{"}ProdTax\text{"}) = Q(R,S) \times IO\_ProdTaxQ_{2010}(R,S) \tag{69}$$

being the share $IO\_ProdTaxQ_{2010}(R,S)$ is the proportion of production taxes over output Q in the base year data.

Social security paid by firms is the sum over industries of the VA component $VAblocks(R,S,\text{"}SocSec\text{"})$:

$$YDSSec^{employer}(R) = \sum^{S} VAblocks(R,S,\text{"}SocSec\text{"}) \tag{70}$$

The remaining two revenue sources are defined above as for equations (42) and (43).

Government total expenditure is the sum of the government interest ($GovInterest$), the government transfers to the households ($YDTran$), the other transfers from the government to the households ($YDOtherTran$), the government capital formation ($Govgfcf$), and the government consumption ($GovCons$):

$$GovTotExp(R) = GovInterest(R) + YDTran(R) + YDOtherTran(R) + \\ +Govgfcf(R) + GovCons(R) \quad (71)$$

The various expenditures are defined as follows. The interest paid by the government is equal to the government debt $GovDebt$ times the interest rate $GovIntRate_{2010}$:

$$GovInterest(R) = GovDebt(R) \times GovIntRate_{2010}(R) \quad (72)$$

The two transfer components ($YDTran$ and $YDOtherTran$) are exogenously fixed to be equal to their base year values. Then, public investment is as follows:

$$Govgfcf(R) = GovCons(R) \times GovSharegfcf_{2010}(R) \quad (73)$$

where $GovSharegfcf_{2010}$ is the proportion of public investment over public consumption as in the base year data. Finally, government consumption can be computed as a constant share of VA as follows:

$$GovCons(R) = \sum^{S} VA(R,S) \times IO\_GovConsVA_{2010}(R) \quad (74)$$

where $IO\_GovConsVA_{2010}$ is the proportion of government consumption over total VA in the base year data. Alternatively, it can be made endogenous and evolving depending on an exogenously determined budget balance path. The model includes a third way to compute government consumption, fixing exogenously its growth rate.[19] In any case, government consumption by region and good is then derived using the WIOD commodity structure of demand in PP for the base year:

$$G\_PP(R,G,"CG") = GovCons(R) \times UseStruct_{2010}(R,G,"CG") \quad (75)$$

The budget balance is calculated as the difference between government revenues ($GovTotRev$) and expenses ($GovTotExp$):

$$GovBdgt(R) = GovTotRev(R) - GovTotExp(R) \quad (76)$$

The level of public debt $GovDebt$ is also calculated in FIDELIO as illustrated below.

$$GovDebt(R) = GovDebt_{t-1}(R) - GovBdgt(R) \quad (77)$$

## 3.4 The trade block

Demand for imports is modelled as a two-step procedure (see Figure 4). First, the share of imports in total demand in BP for each commodity is determined. Second, the trade matrix is used to distribute imports to the country of origin.

The share of imports is equal to the following:

$$MShare(R,G,aU) = \frac{IO\_M_{2010}(R,G,aU)}{IO\_UseBP_{2010}(R,G,aU)} \times \left(\frac{PGdom(R,G,aU)}{PM(R,G,aU)}\right)^{\sigma_{Arm}(R,G)} \quad (78)$$

[19] This is the default option in the current version of FIDELIO.

Where $IO\_M_{2010}$ are the imports by commodity and user for the base year, $IO\_UseBP_{2010}$ the total base year use, $PGdom$ is the domestic commodity price, and $PM$ the import price. $\sigma_{Arm}$ is the first nest Armington elasticity for private consumption taken from the GTAP model,[20] determining the domestic vs imported step.

To derive imports, demand in BP and the endogenous import shares are used:

$$M(R,G,aU) = G\_BP(R,G,aU) \times MShare(R,G,aU) \quad (79)$$

Total imports by region and good are simply summed over users: $Mtot(R,G) = \sum^{aU} M(R,G,aU)$.

The trade shares matrix $TradeShares$ is the second nest of the demand for imports, distributing the demand for imports to the various trading partners. The equation is the following:

$$TradeShares(R,WR,G) = TradeShares_{2010}(R,WR,G) \times PGPartners(R,WR,G)^{-2\sigma_{Arm}(R,G)} \quad (80)$$

where $TradeShares_{2010}$ is the base year import share by trading partner, and $PGPartners$ is the price of the imported products by trading partner.

Then, the matrix of trade flows expressed in free-on-board (FOB) prices and in Unites States dollars is computed. We distinguish between the goods and services for which trade and transport margins are paid (*nTIR* commodities) and the services used to carry out international trade and transport (*TIRS* commodities). The part of the trade matrix related to the *nTIR* commodities is calculated as follows:

$$TradeMatrix(R,WR,nTIR) = \frac{Mtot(R,nTIR) \times XRate_{2010}(R) \times TradeShares(R,WR,nTIR)}{1 + TransitCost_{2010}(R,WR,nTIR)} \quad (81)$$

where $XRate_{2010}$ is the exogenous exchange rate (from WIOD data), while $TransitCost_{2010}$ refers to the international trade and transport margins expressed as % over imports in FOB. The part of the trade matrix containing the services used in international transport is as follows:

$$\begin{gathered} TradeMatrix(R,WR,TIRS) = TradeShares(R,WR,TIRS) \times \\ \times \left[Mtot(R,TIRS) \times XRate_{2010}(R) + \sum^{WR} TIRMatrix(R,TIRS)\right] \end{gathered} \quad (82)$$

The matrix of international trade and transport margins $TIRMatrix$ (difference between trade matrix in CIF viewed from the importer point of view and trade matrix in FOB viewed from the exporter point of view) is obtained as follows:

$$TIRMatrix(R,WR,nTIR) = TradeMatrix(R,WR,nTIR) \times TransitCosts_{2010}(R,WR,nTIR) \quad (83)$$

$$TIRMatrix(R,WR,TIRS) = \sum^{nTIR}[TIRMatrix(R,WR,nTIR) \times TIRShares_{2010}(R,WR,nTIRS,TIRS)] \quad (84)$$

where $TIRShares_{2010}$ redistributes over the TIRS commodities the transport costs based on the base year data.

These imports-related variables are used to derive exports according to the following equation:

$$G\_PP(R,G,"X") = \frac{\sum^{R1} TradeMatrix(R1,R,G)}{XRate(R)} + XRow_{2010}(R,G) \quad (85)$$

[20] https://www.gtap.agecon.purdue.edu/

where $XRow_{2010}$ contains all exports of the FIDELIO countries to those not explicitly modelled into it based on 2010 data.

## 3.5 The relationship between BP and PP, and the calculation of GDP

Demand in BP is derived from demand in PP by subtracting TlS and TTM as shown by equation (3). TlS are defined in equation (67); regarding TTM the relevant equations are the following:

$$TTMpaid(R,G,aU) = [G\_PP(R,G,aU) - TlS(R,G,aU)] \times MrgPaid_{2010}(R,G,aU) \quad (86)$$

where $MrgPaid_{2010}$ is calculated as TTM divided by Use values in PP minus TlS when TTM are positive. If negative, then:

$$TTMrec(R,G,aU) = \sum^{G} TTMpaid(R,G,aU) \times MrgRec_{2010}(R,G,aU) \quad (87)$$

where $MrgRec_{2010}$ is equal to the share of TTM received over the total TTM paid in the base year. Now all the necessary elements are defined in order to derive domestic demand by region, good and user, equation (2), and total demand in BP, equation (3).

The gross domestic product (GDP) is calculated in two alternative ways (which yield the same values), either from VA or from final demand minus imports:

$$GDP(R) = \sum^{S} VA(R,S) + \sum^{aU}\sum^{G} TlS(R,G,aU)) \quad (88)$$

$$GDP(R) = \sum^{aC}\sum^{G} G\_PP(R,G,aC) - \sum^{aU}\sum^{G} M(R,G,aU)) \quad (89)$$

## 3.6 The labour market

We assume that the wage equation is specified as a Wage Setting (WS) curve with a unit indexation of wages $PL$ on the consumer price index $PCP$ and the productivity computed as real output over employment $\frac{Qreal}{Empl}$:

$$ln(PL(R,S,LSca)) = ln(PCP_{t-1}(R)) + ln\left(\frac{Qreal_{t-1}(R,S)}{Empl_{t-1}(R,S)}\right) + \alpha_1^{PL} \times UnempRate_{t-1}(R) \quad (90)$$

Where $\alpha_1^{PL}$ by default takes the value of 0.5. Although WS curve estimations differ across empirical studies, this value corresponds to the average estimation on OECD countries found in Tyrvaïnen (1995) and Van der Horst (2002). The unemployment rate ($UnempRate$) is calculated as follows:

$$UnempRate(R,LS) = \frac{LSupply(R,LS) - \sum^{S} Empl(R,S,LS)}{LSupply(R,LS)} \quad (91)$$

Labour supply is exogenous and equal to the following:

$$LSupply(R,LS) = Pop(R) \times LSupplyRate_{2010}(R,LS) \quad (92)$$

Where $Pop$ is the total population by country, and $LSupplyRate_{2010}$ the participation rate by skill level (from base year data).

Employment can be found with the following equation:

$$Empl(R,S,LSca) = \frac{SkillShares_{2010}(R,S,LSca) \times [VAblocks(R,S,"wages") + VAblocks(R,S,"SocSec")]}{PL(R,S,LSca)} \quad (93)$$

Where $SkillShares_{2010}$ are the shares of skill groups.

And total employment is simply equal to: $Empl(R,S,"all") = \sum^{LSca} Empl(R,S,LSca)$.

## 3.7 The energy block

The real value of the energy factors calculated in the production block is linked to energy consumption in tera-joules (TJ) via fixed coefficients according to the following equation:

$$EnergyTJ(R,S) = IO\_EnergyTJ_{2010}(R,S) \times \frac{Energy(R,S)}{PInputs(R,S,"E")} \quad (94)$$

where $IO\_EnergyTJ_{2010}$ is the inverse of the average price of energy, computed as the sectoral demand of energy in TJ over the sectoral demand of energy in values.

Then, a variable called *InputFuel* is created in order to distribute the energy consumption across the eleven energy carriers (see the *EnCd* set) featured in FIDELIO:

$$InputFuel(R,S,EnCd) = EnergyTJ(R,S) \times \sum^{EnC}[RealEnShares(R,S,EnC) \times Bridge\_EnCd_{2010}(R,S,EnC,EnCd)] \quad (95)$$

where $Bridge\_EnCd_{2010}$ is a fixed bridge matrix whose first eleven entries for four Austrian industries are shown in Table 4 below.

The exogenous energy shares used in equation (95) $RealEnShares$ are calculated outside the model with all exogenous parameters using a translog framework taking into account the exogenous prices of the five *EnC* energy carriers and a number of parameters estimated econometrically. The same data are also used to calculate the exogenous price of the energy input $PInputs(R,S,"E")$ used in equation (94).

**Table 4 First eleven entries of the EnC-EnCd bridge matrix**

| R | EnC | EnCd | A01 | A02 | A03 | B |
|---|---|---|---|---|---|---|
| AUT | *Oil* | *Diesel* | 0.96 | 0.00 | 0.00 | 0.92 |
| AUT | *Oil* | *Gasoline* | 0.00 | 0.00 | 0.00 | 0.00 |
| AUT | *Oil* | *Jetfuel* | 0.00 | 0.00 | 0.00 | 0.00 |
| AUT | *Oil* | *Fueloil* | 0.04 | 0.00 | 0.00 | 0.08 |
| AUT | *Gas* | *Othgas* | 0.00 | 0.00 | 0.00 | 0.00 |
| AUT | *Gas* | *Liquid* | 0.53 | 1.00 | 0.98 | 0.00 |
| AUT | *Gas* | *Natgas* | 0.47 | 0.00 | 0.02 | 1.00 |
| AUT | *Coal* | *Coal* | 1.00 | 0.00 | 0.00 | 1.00 |
| AUT | *ElHeat* | *Electr* | 1.00 | 0.00 | 0.00 | 1.00 |
| AUT | *Renewables* | *Waste* | 0.00 | 0.00 | 0.00 | 0.00 |
| AUT | *Renewables* | *Renewables* | 1.00 | 1.00 | 0.00 | 1.00 |

Carbon dioxide ($CO_2$) emissions related to production are calculated using the $InputFuel$ variable and a set of fixed coefficients $IOEm\_CO2_{2010}$ calculated using Eurostat emissions data according to the following equation:

$$Em\_CO2(R,S,EnCd) = IOEm\_CO2_{2010}(R,S,EnCd) \times InputFuel(R,S,EnCd) \quad (96)$$

Emissions of methane ($CH_4$) and nitrous oxide ($N_2O$) related to production are modelled in a simpler way, using output coefficients calculated with the base year data for emissions and output directly within the model:

$$Em\_CH4(R,S) = IOEm\_CH4_{2010}(R,S) \times \frac{Q(R,S)}{PQ(R,S)} \quad (97)$$

$$Em\_N2O(R,S) = IOEm\_N2O_{2010}(R,S) \times \frac{Q(R,S)}{PQ(R,S)} \quad (98)$$

Where $IOEm\_CH4_{2010}$ and $IOEm\_N2O_{2010}$ are respectively the fixed emissions coefficient over output for $CH_4$ and $N_2O$ for the base year data.

$CO_2$ emissions directly related to household consumption are also modelled in FIDELIO. Similarly to production-related emissions, household energy consumption in TJ is firstly calculated in the following way:

$$EnergyTJHH(R,CPEn) = IO\_EnergyTJHH_{2010}(R,CPEn) \times \frac{CPComm(R,CPEn)}{PCPEnergy(R,CPEn)} \quad (99)$$

$PCPEnergy(R,CPEn)$ is the price of energy consumed by households and it is an exogenous variable. The fixed factor relating consumption of energy goods and consumption of energy in TJ $IO\_EnergyTJHH_{2010}$ (the inverse of the price of energy) is calculated using the base year data for those variables. The factors for the first eight countries of such matrix are shown in Table 5 below.

**Table 5 First eight entries of the IO_EnergyTJHH matrix**

| R | Heating | Electricity | Fuel |
|---|---|---|---|
| AUT | 42.85 | 42.85 | 10.61 |
| BEL | 41.06 | 41.06 | 13.90 |
| BGR | 42.80 | 42.80 | 9.83 |
| BRA | 3.16 | 3.16 | 1.42 |
| CHN | 0.22 | 0.22 | 0.06 |
| CYP | 32.20 | 32.20 | 21.98 |
| CZE | 1.71 | 1.71 | 1.26 |
| DEN | 3.76 | 3.76 | 1.50 |

$CO_2$ emissions are then calculated thanks to one bridge matrix from consumption of energy goods to detailed energy carriers ( $Bridge\_EnCdHH_{2010}$ ) and to $CO_2$ emissions coefficients ($IOEm\_CO2HH_{2010}$) computed from 2010 emissions data by detailed energy carrier. This leads to $CO_2$ household emissions by region and by detailed energy carrier:

$$Em\_CO2HH(R,EnCd) = \\ = \sum^{CPEn}[EnergyTJHH(R,CPEn) \times Bridge\_EnCdHH_{2010}(R,CPEn,EnCd) \times IOEm\_CO2HH_{2010}(R,EnCd)] \quad (100)$$

The Austrian numbers of the $Bridge\_EnCdHH_{2010}$ matrix are contained in Table 6 below.

**Table 6 Austrian bridge matrix between CPEn and the detailed energy carriers**

| | Heating | Fuel | Electricity |
|---|---|---|---|
| *Diesel* | 0.000 | 0.633 | 0.000 |
| *Gasoline* | 0.000 | 0.367 | 0.000 |
| *Jetfuel* | 0.000 | 0.000 | 0.000 |
| *Othgas* | 0.000 | 0.000 | 0.000 |
| *Waste* | 0.000 | 0.000 | 0.000 |
| *Coal_coke_crude* | 0.009 | 0.000 | 0.009 |
| *Fuel_oil* | 0.185 | 0.000 | 0.185 |
| *Liquid_gaseous_biofuels* | 0.042 | 0.000 | 0.042 |
| *Electr_heatprod* | 0.361 | 0.000 | 0.361 |
| *Renewables_nuclear* | 0.213 | 0.000 | 0.213 |
| *Natgas_lpg_othpetro* | 0.189 | 0.000 | 0.189 |

### 3.8 The pricing system

Almost all prices ultimately derive from the output prices $PQ(R,S)$. Also, all prices are normalized to unit value for the base year.

In accordance with the production block, the price of output is based on the CES production structure:

$$PQ(R,S) = \alpha^{KLE}(R,S) \times (P\_KLE(R,S))^{1-\sigma^{KLE\_M}(R,S)} + \alpha^{M}(R,S) \times (P\_SM(R,S))^{1-\sigma^{KLE\_M}(R,S)} \quad (101)$$

The price of the combined capital, energy, and labour inputs ($P\_KLE$) is defined as:

$$P\_KLE(R,S) = \left[\alpha^{C}(R,S) \times \left(\frac{PInputs(R,S,"Capital")}{fprod(R,S,"Capital")}\right)^{1-\sigma^{KLE}(R,S)} + +\alpha^{L}(R,S) \times \left(\frac{PInputs(R,S,"L")}{fprod(R,S,"L")}\right)^{1-\sigma^{KLE}(R,S)} + \alpha^{E}(R,S) \times \left(\frac{PInputs(R,S,"E")}{fprod(R,S,"E")}\right)^{1-\sigma^{KLE}(R,S)}\right]^{\frac{1}{1-\sigma^{KLE}(R,S)}} \quad (102)$$

While the price of combined imported and domestic materials ($P\_SM$) is:

$$P\_SM(R,S) = \sum^{neG} PM(R,neG,S) \times MShare(R,neG,S) \times \frac{IO\_USE_{PP_{2010}}(R,neG,S)}{\sum^{neG} IO\_USE_{PP_{2010}}(R,neG,S)} + + \sum^{neG} PGdom(R,neG,S) \times \left(1 - MShare(R,neG,S)\right) \times \frac{IO\_USE_{PP_{2010}}(R,neG,S)}{\sum^{neG} IO\_USE_{PP_{2010}}(R,neG,S)} \quad (103)$$

The price of domestic commodities is the weighted average of output prices, the weights being the industries' market shares:

$$PG(R,G) = \sum^{S} PQ(R,S) \times MktShares^{make}_{2010}(R,G,S) \quad (104)$$

The domestic price including margins and TIS is the following:

$$PGdom(R,G,aU) = PG(R,G) \times BPStruct_{2010}(R,G,aU) + +PTTM(R,aU) \times TTMStruct_{2010}(R,G,aU) \quad (105)$$

where$BPStruct_{2010}$ and $TTMStruct_{2010}$ are the proportion of BP and TTM, respectively, calculated on the base year data. As for $PTTM$, it is the price of TTM, and its equation is the following:

$$PTTM(R,aU) = \sum^{G} TTMStruct_{2010}(R,G,aU) \times PG(R,G) \tag{106}$$

The import price for pairs of trading partners including transit costs is defined by the following equation:

$$PGPatners(R,R1,G) = PGdom(R1,G,"X") \tag{107}$$

As for the prices of the rest of the world, we assume that:

$$PGPatners(R,"ROW",G) = \frac{PGdom("BRA",G,"X") + PGdom("IND",G,"X")}{2} \tag{108}$$

Import prices at the border (CIF) are as follows:

$$PMcif(R,G) = \sum^{WR}[PGPartners(R,WR,G) \times TradeShares(R,WR,G)] \tag{109}$$

Import prices in PP (including TlS and TTM) are as follows:

$$\begin{gathered} PM(R,G,aU) = PMcif(R,G) \times BPStruct_{2010}(R,G,aU) + \\ + PTTM(R,aU) \times TTMStruct_{2010}(R,G,aU) \end{gathered} \tag{110}$$

The price of commodities is a weighted average of domestic and import prices:

$$\begin{gathered} PUse(R,G,aU) = PM(R,G,aU) \times MShare(R,G,aU) + \\ + PGdom(R,G,aU) \times [1 - MShare(R,G,aU)] \end{gathered} \tag{111}$$

The total costs for each user is then calculated as follows:

$$PUseTot(R,aU) = \frac{\sum^{G} PUse(R,G,aU) \times G\_PP(R,G,aU)}{\sum^{G} G\_PP(R,G,aU)} \tag{112}$$

The consumer price is *PUseTot* for the household industry: *PUseTot(R,"CP")*. The prices of the consumption commodities are found using the CPA-COICOP bridge:

$$\begin{gathered} PComm(R,CPC) = \sum^{G}\{[PGdom(R,G,"CP") \times (1 - MShare(R,G,"CP")) + PM(R,G,"CP") \times (MShare(R,G,"CP"))] \times \\ \times CPBridge_{2010}(R,G,CPC)\} \end{gathered} \tag{113}$$

The following prices are exogenous and 2010-2050 time series are imported and used in FIDELIO: *PElec*, *PFuel*, and *PHeat* are used in equations (54), (55), and (56), respectively; the price of the energy input is also exogenous and derived as explained in Subsection 3.7. The prices of the production inputs are illustrated by the equations below (the price of energy is missing below because exogenously determined in the energy block as explained above).

$$PInputs(R,S,"Capital") = \sum^{G} [PUse(R,G,"Invest") \times IStruct_{2010}(R,G,S)] \tag{114}$$

$$PInputs(R,S,"L") = \frac{PL(R,S,"all")}{Base\_PL(R,S,"all")} \tag{115}$$

where $Base\_PL$ is equal to the base year wage per hour in the baseline run, and then equal to the baseline $PL$ in the simulation runs. The following equation defines $PL$ for all workers:

$$PL(R,S,"all") = \sum^{LSca} PL(R,S,LSca) \times SkillShares(R,S,LSca) \tag{116}$$

# 4 The data of FIDELIO

The bulk of the dataset of the third version of FIDELIO lies in the IO dataset coming from WIOD, as explained in Subsection 4.1. The rest of the data come from various sources as explained in Subsection 4.2.

## 4.1 The IO dataset

This Subsection describes the IO data. The main part comes from the WIOD dataset (2016 release, the data refer to 2010), in particular the WIOD international supply and use tables. Other WIOD tables, such as the national supply and use tables, are used to apply some required transformations. Whenever the WIOD database does not provide all the necessary information, other databases, such as Eurostat supply and use tables or OECD data were used, as described in the following Subsections. In particular, Subsection 4.1.1 describes the data that constitute the IO core. Subsection 4.1.2 explores the issues of international trade and transport margins (ITTM). Finally Subsection 4.1.3 focuses on data about VA.

### 4.1.1 Supply, use, and trade

The main data coming from the WIOD international supply and use tables are contained in a matrix of entries by region, by industry and by commodity. These are data on supply, use, and trade. Supply data are used to fill a "Make" column. Use data provide the demand values in PP and BP, the difference between the two being constituted by TlS and TTM. Use data also contain information about international trade flows: one category of final users is exports by product. An imports ("M") column completes the matrix with the values of imported commodities. Since in the international use table imports are expressed in FOB terms, they are re-expressed in cost-insurance-and-freight (CIF) terms adding the ITTM to the value of imported goods.[21] WIOD international supply and use tables are used to produce those data, as well as the trade shares. Data are split in 56 products and 56 activities, expressed in millions of dollars (exchange rates are used to convert those into own currencies). Table 7 contains the first eight entries of this part of the dataset.

**Table 7 First eight entries of the IO Make and Use data**

| R | G | aU | Make | PP | TlS | TTM | BP | M |
|---|---|---|---|---|---|---|---|---|
| AUT | CPA_A01 | A01 | 5376.41 | 1298.39 | 0.15 | 38.24 | 1260.00 | 262.24 |
| AUT | CPA_A02 | A01 | 0.00 | 7.35 | -0.02 | 1.62 | 5.75 | 1.50 |
| AUT | CPA_A03 | A01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AUT | CPA_B | A01 | 3.90 | 15.19 | 0.01 | 3.10 | 12.08 | 10.96 |
| AUT | CPA_C10-C12 | A01 | 687.86 | 640.91 | 1.09 | 59.03 | 580.79 | 104.25 |
| AUT | CPA_C13-C15 | A01 | 0.00 | 21.05 | 0.12 | 4.82 | 16.11 | 16.11 |

[21] In the WIOD international use table ITTM are shown as a separate column. To get consistency between FIDELIO data and FIDELIO model we add ITTM to the value of exported transport and trade services (Subsection 4.1.2 describes how ITTM by product provided by WIOD are attributed to ITTM services).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AUT | CPA_C16 | A01 | 18.48 | 36.23 | 0.04 | 6.02 | 30.17 | 10.61 |
| AUT | CPA_C17 | A01 | 0.00 | 11.44 | 0.01 | 2.37 | 9.06 | 5.08 |

Note: imports are expressed in CIF.

The exchange rates used are contained in Table 8 below:

**Table 8 Exchange rates used in FIDELIO**

| | | | | |
|---|---|---|---|---|
| AUT: 1.326 | DEU: 1.326 | GRC: 1.326 | LTU: 1.327 | ROU: 0.315 |
| BEL: 1.326 | DEN: 0.178 | HRV: 0.182 | LUX: 1.326 | RUS: 0.033 |
| BGR: 0.678 | ESP: 1.326 | HUN: 0.005 | LVA: 1.330 | SVK: 1.326 |
| BRA: 0.568 | EST: 1.328 | IND: 0.022 | MLT: 1.326 | SVN: 1.326 |
| CHN: 0.148 | FIN: 1.326 | IRL: 1.326 | NLD: 1.326 | SWE: 0.139 |
| CYP: 1.326 | FRA: 1.326 | ITA: 1.326 | POL: 0.333 | TUR: 0.666 |
| CZE: 0.052 | GBR: 1.546 | JPN: 11.415 | PRT: 1.326 | USA: 1.00 |

Note: US$ per unit of local currency.

Two additional data sources are used in order to get TTM and TlS data:

- WIOD national supply and use tables for the year 2010 (release 2016). These tables, available for 43 countries, are split in 64 products and 64 industries, and are expressed in millions of national currencies (except for Bulgaria, Cyprus, Estonia, Greece, Croatia, Lithuania, Luxembourg, Latvia, Malta, Portugal, Romania, Slovak Republic, Slovenia that are expressed in dollars). Countries not included in FIDELIO are aggregated into the rest of the world, and industries and products are aggregated in order to match the 56 categories used in FIDELIO.
- EUROSTAT tables (use table at PP T1600, use table at BP T1610, TTM table T1620, TlS table T1630), with information for 28 European countries, split in 65 products and 65 activities. Data are in millions of euro. Once again, an aggregation of products and activities is needed in order to match the FIDELIO categories.

The procedure for the EU countries is as follows. For TlS and TTM, WIOD national supply tables provide a column for TTM and a column for TlS split by product, and national use tables provide a vector for TlS split by activity. Additionally, we use EUROSTAT TTM and TlS tables (T1620and T1630) that offer information on TTM and TlS split by product and by activity. EUROSTAT tables do not contain information on TTM for Croatia (Greece is used as a proxy). In order to compute TTM and TlS split by product and by activity, we compute the share of TTM (and TlS) over total use, by product and by activity, using EUROSTAT data (use tables T1610, TTM tables T1620, and TlS tables T1630). Then, we multiply the shares for the WIOD use, by product and by activity (from the national USE tables), obtaining in this way a matrix of TTM and a matrix of TlS. The matrices obtained are not consistent with the total TTM and TlS columns and the total TlS row provided by WIOD. So, for each country we run a GRAS (Generalized RAS) to adjust the matrix obtained to the total WIOD.

Two problems arise from the applied procedure. First, for some countries, the GRAS procedure does not converge (Slovakia for TTM and Estonia, Greece, Malta, and Portugal for TlS). Other procedures were tested (such as applying a RAS considering the WIOD total TlS vector and column and the WIOD use matrix; or estimating the TlS matrix using the WIOD use matrix proportions; or adjusting the WIOD total TlS row and the gross operating surplus), but no one was able to provide useful results. As a solution for these five tables we computed TTM or TlS using only WIOD information, splitting the WIOD totals based on the use table structure. Second, as a result of the procedure used, for the

TTM products (such as CPA-G46, CPA-G47) the estimated TTM might be greater than the value in the use table in basic prices and opposite in sign, resulting in a negative use in PP. As a solution we relax the WIOD totals by product to the extent necessary to avoid negative values in the use data in PP. We keep fixed the total by activity, that is equal to zero in the case of TTM, and that determines the value added in the case of TlS.

For non-EU countries we apply the same procedure as for EU countries. Since EUROSTAT data are available only for EU countries, we use the average of the EU countries to get TTM and TlS shares by product and by activity. As for EU countries, these shares are multiplied for the WIOD use by product and by country (from the national USE tables), obtaining in this way a matrix of TTM and a matrix of TlS. Since these matrices have to be consistent with the total TTM and TlS columns and the total TlS row provided by WIOD, for each country we run a GRAS to adjust the matrix obtained.

WIOD data on TlS and TTM is not complete for all non-EU countries. TTM information is available only for Brazil and Turkey, thus these are the only countries for which TTM are computed at the moment. These are the only countries that have complete information also for TlS. For three other countries, India, Russia, and USA, only the row vector TlS split by activity in the USE tables is available, while the column vector of TlS split by product in the supply tables is missing. For these countries we compute the column vector of TlS split by product distributing the WIOD country-total TlS using the EUROSTAT proportions. Due to data availability, for Japan and China there is no estimation of TTM and TlS.

Trade shares are computed using the information from WIOD international use tables from which import data are taken. They show, for each product and each country, what share is imported from what trading partner. Shares sum to one across trading partners for each commodity. Table 9 shows the first eight entries of that matrix.

**Table 9 First eight entries of the trade shares matrix**

| Importer | Exporter | G | TradeShares |
|---|---|---|---|
| AUT | AUT | CPA_A01 | - |
| AUT | BEL | CPA_A01 | 0.0322 |
| AUT | BGR | CPA_A01 | 0.0035 |
| AUT | CYP | CPA_A01 | 0.0008 |
| AUT | CZE | CPA_A01 | 0.0454 |
| AUT | DEN | CPA_A01 | 0.0031 |
| AUT | DEU | CPA_A01 | 0.2534 |
| AUT | ESP | CPA_A01 | 0.0651 |

Finally, another piece of information related to trade is required to have consistent data on imports and exports. Imports are the total imports only of FIDELIO countries, while exports measure exports to all countries. To get consistency between these two flows it is necessary to introduce an additional variable that is exports to the rest of the world. Although not explicitly modelled in FIDELIO, exports to the rest of the world are added to the countries' mirror exports (exports derived from import data) in order to make sure that total exports (derived from import data) reflect actual total exports in the data. Exports to the rest of the world are also adjusted in order to include ITTM services.

The first eight entries of this matrix are shown in Table 10 below.

**Table 10 First eight entries of the matrix of exports to the rest of the World**

| R | G | Exports to RoW |
|---|---|---:|
| AUT | CPA_A01 | 92 |
| AUT | CPA_A02 | 11 |
| AUT | CPA_A03 | 0 |
| AUT | CPA_B | 116 |
| AUT | CPA_C10-C12 | 1148 |
| AUT | CPA_C13-C15 | 642 |
| AUT | CPA_C16 | 672 |
| AUT | CPA_C17 | 742 |

### 4.1.2 International trade and transport margins

Since imports data in the international use table are expressed in FOB, such data do not contain ITTM. For each country, the international use table makes available an ITTM vector by product and by origin country and an ITTM row by activity, but not split by origin country. In order to get to that level of disaggregation, and using the available information, first we need to estimate how ITTM are split by product/activity/origin country, and second to estimate how ITTM are assigned to ITTM services (the *TIRS* set made by the CPA-G and CPA-H services).

We apply the following procedure. As a first step, since in national use tables imports are expressed in CIF, from the difference between the national use table and the consolidated international use table we compute a matrix of ITTM split by product and by activity for each WIOD country. The matrix obtained is not disaggregated by trading partner. To split the ITTM matrix by trading partner, for each country we use the horizontal structure of the consolidated ITTM matrix obtained, and the vector of ITTM split by product and by origin. Applying the structure to the WIOD total vector, for each country we disaggregate the ITTM matrix product/activity/origin country. For each country the sum of ITTM by activity (sum by column) obtained corresponds to the ITTM row by activity available in the WIOD international use table. The obtained ITTM split by product and user are added to import (to express them in CIF value) and to the total use vector at basic prices.

Then, we need to distribute the ITTM obtained to the TTM services (CPA-G and CPA-H). To distribute them, the main source used is the WIOD world IO table (WIOT). Since WIOT is expressed in basic prices, the table allocates TTM imported by each trading partner to TTM services (CPA-G and CPA-H). We assume that ITTM services have the same distribution as TTM services. Applying this assumption, from WIOT table we compute the ITTM services distribution in two different ways. A first estimation assumes that all ITTM associated to goods imported from one trading partner are provided by that trading partner. Under this assumption we compute the ITTM services applying the TTM structure of each trading partner. A second estimation assumes that ITTM associated to goods imported from one trading partner might be provided by another trading partner. Under this assumption we compute the ITTM services applying the TTM structure computed on the total TTM services imported by each country from all trading partners. The estimated ITTM services are added to the export vector at basic prices.

The same structure obtained under the first method is also used to compute the TIR shares that show how ITTM associated to any goods are allocated to the different ITTM services (see Table 11 to understand how those data are organised). TIR shares are split by product and by origin country, as required in FIDELIO. Both ITTM by product and by industry and ITTM services by industry are then used, jointly to TTM, to transform the USE vector from BP to PP.

**Table 11 First eight entries of the matrix splitting ITTM among the TIRS commodities**

| Imp | Exp | G | CPA_G45 | CPA_G46 | CPA_G47 | CPA_H49 | CPA_H50 | CPA_H51 | CPA_H52 | CPA_H53 |
|---|---|---|---|---|---|---|---|---|---|---|
| BEL | AUT | CPA_A01 | 0.022 | 0.314 | 0.020 | 0.547 | 0.001 | 0.001 | 0.094 | 0.001 |
| BGR | AUT | CPA_A01 | 0.050 | 0.783 | 0.031 | 0.099 | 0.003 | 0.008 | 0.024 | 0.003 |
| CYP | AUT | CPA_A01 | 0.026 | 0.480 | 0.021 | 0.382 | 0.001 | 0.004 | 0.070 | 0.017 |
| CZE | AUT | CPA_A01 | 0.053 | 0.795 | 0.032 | 0.071 | 0.002 | 0.006 | 0.041 | 0.001 |
| DEU | AUT | CPA_A01 | 0.058 | 0.700 | 0.031 | 0.146 | 0.002 | 0.008 | 0.055 | 0.000 |
| DEN | AUT | CPA_A01 | 0.048 | 0.840 | 0.030 | 0.052 | 0.002 | 0.006 | 0.021 | 0.001 |
| ESP | AUT | CPA_A01 | 0.051 | 0.760 | 0.030 | 0.132 | 0.001 | 0.000 | 0.025 | 0.000 |
| EST | AUT | CPA_A01 | 0.052 | 0.784 | 0.033 | 0.072 | 0.002 | 0.006 | 0.049 | 0.002 |

Finally, another input required is transit cost shares, computed as ITTM as % of imports expressed in FOB. Table 12 below shows the first eight entries of the ITTM as % of imports in FOB:

**Table 12 First eight entries of the transit cost shares matrix**

| Importer | Exporter | G | Transit cost shares |
|---|---|---|---|
| AUT | BEL | CPA_A01 | 0.0360 |
| AUT | BEL | CPA_A02 | 0.0434 |
| AUT | BEL | CPA_A03 | 0.0874 |
| AUT | BEL | CPA_B | 0.0396 |
| AUT | BEL | CPA_C10-C12 | 0.0572 |
| AUT | BEL | CPA_C13-C15 | 0.0460 |
| AUT | BEL | CPA_C16 | 0.0535 |
| AUT | BEL | CPA_C17 | 0.0448 |

### 4.1.3 The VA components

For EU countries, VA components are calculated using WIOD international use table and EUROSTAT use tables. WIOD does not split the total VA (available by activity) in its five components as required in FIDELIO, while the EUROSTAT database has such information. In order to calculate the FIDELIO data, the WIOD total VA by activity is taken from the international use tables (it is the same as in the national use tables), and it is split into the five components by applying the ratios computed with EUROSTAT data (EUROSTAT components are taken from the use table at basic prices T1610; EUROSTAT total VA is taken either from the use table T1610 or from the use table at PP T16 depending on data availability for each country). For some countries, EUROSTAT data do not have all components. For Spain and France, gross operating surplus (B2A3G) is not split between net operating surplus (B2A3N) and depreciation (P51C). For France and Ireland, Compensation of employees (D1) is not split between wages (D11) and social security contribution (D12). In these cases we apply the average of the EU countries by activity to obtain the missing information.

Codes reported in Table 13 are used in the discussion below for the sake of brevity. For non-EU countries, the total VA by activity comes once again from WIOD data. In order to split total VA in its components, different sources are used depending on the country. The main databases used are OECD data, World Bank data, and data from National Statistical Institute for China, India, and Turkey. Please see below the country-specific details.

**Table 13 VA components and their codes**

| VA components | | Code |
|---|---|---|
| Production taxes less subsidies | | D29x39 |
| Depreciation (consumption of fixed capital) | | P51C |
| Net operating surplus | | B2A3N |
| | Gross operating surplus | B2A3G |
| Wages | | D11 |
| Social security contributions | | D12 |
| | Compensation of employees | D1 |

- Brazil:
  - D29x39 by activity comes from OECD data for the year 2010 (Table 41: Use, Value added and its components, GFCF and assets by activity[22]);
  - P51C by activity is computed using the indicator provided by the World Bank on consumption of fixed capital as % of gross national income for the year 2010.[23] This indicator is used as a proxy of P51C as % of VA. The indicator is available only at the country level, and it has been applied to all industries by multiplying the country-level indicator by the total VA by activity;
  - B2A3N is computed as the difference between B2A3G and P51C. Data on B2A3G by activity come from OECD data for the year 2010 (Table 41);
  - D11 by activity comes from the same OECD data as D29x39. D12 by activity is computed as the difference between D1 and D11. D1 by activity is again taken from the OECD table no. 41.
- China:
  - D29x39 is taken from the Chinese IO table disaggregated in 41 activities (the table was obtained from the National Bureau of Statistics of China);
  - P51C taken from Chinese IO table disaggregated in 41;
  - B2A3N is also taken from the Chinese IO table;
  - since information is not available for D11, we apply the average of the shares of Russia and Brazil (by activity) to the total D1 of China (by activity). The same goes for D12. D1 by activity is again taken from the IO table for China.
- India:
  - D29x39 by activity comes from national statistics (Ministry of Statistics, Government of India: national Accounts[24]). Data are available for the years 2011-2012;
  - P51C by activity also comes from national statistics as D29x39;

[22] http://stats.oecd.org/index.aspx?DatasetCode=SNA_TABLE41
[23] http://data.worldbank.org/indicator/NY.ADJ.DKAP.GN.ZS?locations=IN-US-BR-CN
[24] http://mospi.nic.in/publication/national-accounts-statistics-2016

- B2A3N by activity also comes from national statistics;
- since information is not available for D11 and D12, we apply the average of the shares of Russia and Brazil (by activity) to the total D1of India (by activity). Data on D1 by activity are available from national statistics.

- Japan:
  - D29x39 by activity comes from OECD data for the year 2011 (Table 6A: Value added and its components by activity, ISIC rev4[25]);
  - P51C by activity comes from the same OECD dataset as D29x39;
  - B2A3N by activity also comes from the OECD dataset above;
  - D11 is computed using OECD data (Table 14A: Non-financial accounts by activity[26]). The OECD non-financial accounts report D1 and D11 at the country level. These data are used to compute D11 as a share of D1 which is then applied to D1 data by activity available from table 6A of the OECD. D12 by activity is then computed as the difference between D1 and D11.
- Russia:
  - D29x39 by activity comes from OECD data for the year 2011 (Table 6: Value added and its components by activity, SNA93[27]);
  - P51C by activity is computed using information on consumption of fixed capital at the country level for the year 2011 taken from OECD data (Table 2: Disposable income and net lending - net borrowing[28]). This information is used to compute the share of P51C over B2A3G at the country level (B2A3G comes from the OECD table no. 6). The latter share is then applied to calculate P51C by activity using data on B2A3G by activity again taken from table 6 of the OECD;
  - B2A3N is computed as the difference between B2A3G and P51C;
  - D11 by activity also comes from the OECD table no. 6 for the year 2011. D12 by activity is computed as the difference between D1 and D11. D1 also comes from OECD table 6.
- Turkey:
  - D29x39 by activity comes from the Use table published by the Turkish Statistical Institute for the year;[29]
  - P51C by activity comes from the same source as D29x39. Note that depreciation is equal to zero with the exception of nine activities;
  - B2A3N by activity again comes from the same national data as above;
  - D11 is computed using OECD data for year 2011 (Table 6A, as for Japan). The OECD data reports D1 and D11 at the country level. These data are used to compute D11 as a share of D1, then applied to data on D1 by activity available from the Turkish national data. D12 by activity is computed as the difference between D1 and D11.
- USA:
  - D29x39 by activity come from OECD data for the year 2011 (Table 41, as for Brazil);
  - P51C by activity comes from the same Table 41 by OECD;

[25] http://stats.oecd.org/index.aspx?DatasetCode=SNA_TABLE6A
[26] https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE14A
[27] http://stats.oecd.org/index.aspx?DatasetCode=SNA_TABLE6_SNA93
[28] https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE2
[29] http://www.turkstat.gov.tr/PreTablo.do?alt_id=1021

- B2A3N by activity also comes from the OECD Table 41. data, year 2011;
- D11 and D12 by activity again come from the same OECD table above;

In order to illustrate the data, Table 14 shows the totals and the data for first eight industries for the case of Austria.

**Table 14 First eight entries of the VA components for Austria**

| R | VAC | total | A01 | A02 | A03 | B | C10-C12 | C13-C15 | C16 | C17 |
|---|---|---|---|---|---|---|---|---|---|---|
| AUT | *prodtax* | 3950 | -1605 | -87 | 0 | -8 | 43 | -6 | 32 | -6 |
| AUT | *depr* | 51583 | 1626 | 142 | 10 | 319 | 702 | 163 | 362 | 353 |
| AUT | *opsur* | 67876 | 2348 | 816 | 1 | 543 | 1785 | 306 | 548 | 481 |
| AUT | *wages* | 114600 | 248 | 172 | 2 | 271 | 2152 | 530 | 934 | 713 |
| AUT | *socsec* | 24302 | 52 | 36 | 0 | 54 | 425 | 105 | 180 | 164 |

### 4.1.4 The investment data

Three main databases are used in order to produce the investment data for FIDELIO by country, industry, and good. The first one is the "nama_10_a64_p5" Eurostat dataset containing information on gross capital formation by industry and by country. The second is WIOD, used for the information on gross capital formation by commodity and by country. Finally, the investment matrices provided by Belgium, Czech Republic, Hungary, Slovakia, and the United Kingdom are used as bridge matrices for all the countries in FIDELIO.

The first step produces a complete investment matrix for the total gross capital formation ("Total fixed assets (gross)" in NACE Rev. 2 code) for EU countries by activity from the file source "nama_10_a64_p5" which only contains complete information for 14 countries (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, Germany, Greece, Hungary, Ireland, Italy, Portugal, Romania, and Slovakia). For the rest of the countries there is information by activity but only at the level of one-digit NACE Rev. 2 code (with the exception of Croatia and Sweden which only have total gross fixed capital formation available). Then, two different approaches were used to produce the data for the 56 activities for these countries. For the first group (Cyprus, France, Lithuania, Malta, Poland, and Spain), the shares of each specific activity over the NACE Rev. 2 one-digit code total were created by identifying similar countries.[30] Cyprus, Malta, and Spain were estimated with the information available for Italy. Czech Republic was used for Lithuania and Poland, Portugal was used for France. For the second group (Croatia, Estonia, Latvia, Luxembourg, Netherland, Slovenia, and the United Kingdom), the shares of each specific activity were used with respect to the total at the level of one digit code of NACE Rev. 2 of the total assets of the 14 countries that have complete information. As for the rest of the 8 countries of FIDELIO 3 (Brazil, China, India, Japan, Russia, Sweden, Turkey, and the Unites States) that only have the total amount of the "Total fixed assets (gross)" without any breakdown by activity, information was estimated with the average information of the 27 countries previously calculated as explained above.

[30] See methodology for identifying similar countries in "Annex A. Approach to identify similar countries" in Montinari et al. (2016).

The second step produces a complete investment matrix for P51G for the 35 countries of FIDELIO and for 56 commodities at purchases prices estimated from WIOD database.

The third step produces a bridge matrix to estimate all matrices of each country for P51G by 56 industries and by 56 commodities. This bridge matrix was estimated with information related to gross fixed capital formation matrices available for Belgium, Czech Republic, Hungary, Slovakia, and the United Kingdom that have different dimension of industries and commodities. All of them relate to the year 2010, except for Slovakia, which is related to the year 2013. All these 5 matrices were standardized for 56 industries and for 56 commodities and a matrix with the average of the 5 countries was estimated.

Therefore, a GRAS process was implemented using the result for gross fixed capital formation of each country related to the vectors of the 56 industries (Step 1) and the vectors of the 56 commodities (Step 2) combining with the bridge matrix of the step 3. For those countries that had information of gross fixed capital formation in a specific commodity if the bridge matrix does not contain information, the average of the commodities related to the commodities that are at one digit level of the NACE Rev. 2 classification was applied.

## 4.2 The rest of the data: the household block

#### 4.2.1 Household income, taxes, and transfers

Most of the variables characterising the income earned by households, the taxes paid and the transfers received by them come from the Eurostat dataset (nasa_10_nf_tr) "Non-financial transactions of households and non-profit institutions serving households" for the EU28 countries, and from the OECD dataset (no. 13) "Simplified non-financial accounts" for the non-EU countries of the model. We now introduce all the variables needed in order to calculate household disposable income.

The data for household labour wages are taken from the VA data above, corresponding to D1. Operating surplus corresponds to B2A3G (operating surplus and mixed income, gross, received - SB2G_B3G in the OECD dataset). In case of missing data (in this case, for Brazil, India, Russia, and Turkey), operating surplus is calculated as a proportion of operating surplus taken from the VA data, the proportion being the average proportion in the sample (in our case, 0.65). Property income is calculated using D4 (property income) by subtracting paid property income from received property income. The same is done with OECD data, subtracting SD4P from SD4R.

Taxes paid by the households, correspond to D5 (current taxes on income, wealth, etc., paid - SD5P in the OECD dataset). In case of missing data (in this case, for Brazil, India, Luxembourg, Malta, Russia, and Turkey), operating surplus is calculated as a proportion of the sum of wages and social security contributions taken from the VA data, the proportion being the average proportion in the sample (in our case, 0.10). Transfers received by the households come from D62 (social benefits other than social transfers in kind, received minus paid - SD61R_SD62R in the OECD dataset). In case of missing data (in this case, for Brazil, India, Luxembourg, Malta, Russia, and Turkey), transfers are calculated as a proportion of the sum of wages and social security contributions taken from the VA data, the proportion being the average proportion in the sample (in our case, 0.35). Other transfers are also considered: D7, again received minus paid (other current transfers - SD7R minus SD7P in the OECD dataset). Social security contributions are also needed in order to calculate household disposable income. Those paid by the employer are taken from the VA data as explained above. Those paid by the employee, D61 (net social contributions, paid minus received - SD61P_SD62P in the OECD dataset). In case of missing data (in this case, for Brazil, India, Luxembourg, Malta, Russia, and Turkey), social security contributions are calculated as a proportion of the sum of wages and social security contributions taken from the VA data, the proportion being the average proportion in the sample (in our case, 0.11). Finally, household disposable income is calculated in the model according to equation (41) using the variables described so far.

#### 4.2.2 Household consumption

Total consumption is equal to the sum over products of the Use data in PP. Household consumption in FIDELIO 3 differentiates between durable and non-durable commodities. Most of the relevant data come from the Eurostat dataset (nama_10_co3_p3) "Final consumption expenditure of households by consumption purpose - COICOP 3 digit" for the EU28 countries, and from the OECD dataset (no. 5) "Final consumption expenditure of households" for the seven non-EU countries of the model.

The non-durable and non-energy part of the consumption block is organised in a QAIDS that includes the eight following categories: food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other. They are constructed as follows.

- food is the sum of CP01 (food and non-alcoholic beverages) and CP021 (alcoholic beverages);
- clothing corresponds to CP03 (clothing and footwear);
- furniture and equipment is the sum of CP051 (furniture and furnishings, carpets and other floor coverings), CP052 (household textiles), CP054 (glassware, tableware and household utensils), CP055 (tools and equipment for house and garden), and CP056 (goods and services for routine household maintenance);
- health corresponds to CP06 (health);
- communication corresponds to CP08 (communications);
- recreation and accommodation is the sum of CP094 (recreational and cultural services), CP111 (catering services), and CP112 (accommodation services);
- financial services is the sum of CP125 (insurance) and CP126 (financial services n.e.c.);
- other is a residual category made up by the sum of CP022 (tobacco), CP023 (narcotics), CP09 (recreation and culture) excluding CP094, CP10 (education), and CP12 (miscellaneous goods and services) excluding CP125 and CP126.

The non-durable energy commodities considered in FIDELIO 3 are the following:

- electricity and heating, corresponding to CP045 (electricity, gas and other fuels) — due to the lack of data, electricity and heating values are obtained by simply dividing the total value by two;

- fuel for private transport, corresponding to CP072 (operation of personal transport equipment);
- public transport, corresponding to CP073 (transport services).

A variable related to the consumption of electricity and heating is heating degree days, defined as: $(18^{\circ} - T_m) * d$ if $T_m$ is lower than or equal to 15˚C (the temperature below which buildings need to be heated), and nil if $T_m$ is greater than 15˚C. $T_m$ is the mean $(T_{min} - T_{max})/2$ outdoor temperature over a period of $d$ days. The main source for this type of variable is the Eurostat dataset (nrg_esdgr_a) "Heating degree-days by NUTS 2 regions - annual data", under "Energy statistics". As for the countries not included in this dataset, values were assigned depending on the average temperature (for example, Japan was assigned a value close to that of Turkey because the average temperature in the two countries is very similar — 11.15 and 11.10 respectively). Table 15 shows the heating degree days values used in FIDELIO 3.

**Table 15 Heating degree days (Hdd) in 2010**

| R | Hdd | R | Hdd | R | Hdd | R | Hdd |
|---|---|---|---|---|---|---|---|
| AUT | 3301 | EST | 4302 | JPN | 2390 | RUS | 6000 |
| BEL | 2696 | FIN | 5596 | LVA | 4161 | SVK | 3160 |
| BRA | 400 | FRA | 2340 | LTU | 3931 | SVN | 2774 |
| BGR | 2403 | DEU | 3063 | LUX | 2967 | ESP | 1686 |
| CHN | 3200 | GRC | 1449 | MLT | 499 | SWE | 5291 |
| HRV | 2316 | HUN | 2594 | NLD | 2727 | TUR | 2389 |
| CYP | 600 | IND | 400 | POL | 3439 | GBR | 2990 |
| CZE | 3327 | IRL | 2841 | PRT | 1166 | USA | 3050 |
| DEN | 3235 | ITA | 1829 | ROU | 2773 | | |

The following parameters of FIDELIO 3 also affect energy consumption: efficiency of vehicles, heating, and electricity. They refer to the efficiency of private transport vehicles, heating systems and household appliances respectively, and data are taken from the EU Reference Scenario 2016 on energy, transport and GHG emissions containing trends to 2050.[31] Table 16 shows the first four entries of each of those parameters.

**Table 16 First five entries of the three parameters for the efficiency of appliances and vehicles**

| R | Parameters | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| AUT | efficiency_electricity | 1.00 | 0.98 | 0.97 | 0.95 | 0.93 |
| BEL | efficiency_electricity | 1.00 | 0.99 | 0.97 | 0.96 | 0.95 |
| BRA | efficiency_electricity | 1.00 | 0.99 | 0.98 | 0.97 | 0.96 |
| BGR | efficiency_electricity | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| AUT | efficiency_heating | 1.00 | 0.98 | 0.97 | 0.95 | 0.93 |
| BEL | efficiency_heating | 1.00 | 0.99 | 0.97 | 0.96 | 0.95 |
| BRA | efficiency_heating | 1.00 | 0.99 | 0.98 | 0.97 | 0.96 |
| BGR | efficiency_heating | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| AUT | efficiency_vehicles | 1.00 | 0.98 | 0.97 | 0.95 | 0.93 |
| BEL | efficiency_vehicles | 1.00 | 0.98 | 0.96 | 0.94 | 0.92 |
| BRA | efficiency_vehicles | 1.00 | 0.99 | 0.98 | 0.97 | 0.96 |
| BGR | efficiency_vehicles | 1.00 | 0.99 | 0.97 | 0.96 | 0.95 |

[31] Capros, P., A. De Vita, N. Tasios, P. Siskos, M. Kannavou, A. Petropoulos, S. Evangelopoulou et al. "EU Reference Scenario 2016-Energy, transport and GHG emissions Trends to 2050." (2016).

Households in FIDELIO 3 can also spend for vehicles and housing, which are considered as durable goods and treated differently from the non-durable ones. Thus, the following variables are also considered in the model:

- rents, corresponding to the sum of CP041 (actual rentals for housing), CP042 (imputed rentals for housing), CP043 (maintenance of the dwelling), and CP044 (water supply and miscellaneous services relating to the dwelling), corresponding to CP044;
- vehicles, corresponding to CP071 (purchase of vehicles).

The number of households is a parameter used in the equations for the investment in housing and vehicles. Data for such parameter are obtained starting from population data. Population is taken from the UN, which provides projections to 2050 (the medium variant ones are used in FIDELIO 3), and by dividing population by the average size of the household in each country the number of households is obtained. The average household size was calculated thanks to Eurostat data for the EU28 countries and for Turkey, and thanks to UNECE for the US and Russia (for such countries both population and number of households exist for 2010). Census data for the four other non-European countries were used to retrieve the average household size and perform the calculations needed to obtain the number of households from 2010 to 2050. Table 17 shows the average household sizes used in FIDELIO.

**Table 17 Average household size in FIDELIO**

| R | hh size | R | hh size | R | hh size | R | hh size |
|---|---|---|---|---|---|---|---|
| AUT | 2.29 | EST | 2.38 | JPN | 2.39 | RUS | 2.62 |
| BEL | 2.39 | FIN | 2.13 | LVA | 2.47 | SVK | 3.01 |
| BRA | 3.30 | FRA | 2.29 | LTU | 2.27 | SVN | 2.46 |
| BGR | 2.60 | DEU | 2.05 | LUX | 2.47 | ESP | 2.58 |
| CHN | 3.05 | GRC | 2.55 | MLT | 2.88 | SWE | 2.08 |
| HRV | 2.83 | HUN | 2.44 | NLD | 2.25 | TUR | 3.72 |
| CYP | 3.92 | IND | 4.18 | POL | 2.84 | GBR | 2.29 |
| CZE | 2.34 | IRL | 2.74 | PRT | 2.62 | USA | 2.61 |
| DEN | 2.39 | ITA | 2.37 | ROU | 2.69 | | |

Finally, households can also buy appliances, which although durable, are not considered as own houses and vehicles in the model because they cannot be used as collateral. The variable governing the consumption of appliances takes the value of CP053 (household appliances) in the base year.

As stated above, durables are treated differently from the other consumption categories due to the fact that they can be used as collateral, and stocks are built through investment. Investment in vehicles in the model is set to be equal to the expenditure in vehicles. As for investment in dwellings, the base year value of *gfcf_housing* is obtained as the difference between P51G (from the Eurostat nasa_10_nf_tr dataset "Non-financial transactions of households and non-profit institutions serving households") and the expenditure for vehicles.

Table 18 below contains the consumption data for Austria used in FIDELIO. 2009 and 2010 values are used due to the fact that in some cases lagged values of the consumption variables are used (see the equations of the model in Section 3).

**Table 18 Household consumption data for Austria**

| R | COICOP | 2009 | 2010 | COICOP | 2009 | 2010 |
|---|---|---|---|---|---|---|
| AUT | *food* | 17596 | 17917 | *elec_heat* | 6104 | 6285 |
| AUT | *clothing* | 9113 | 9554 | *fuel* | 10362 | 11443 |
| AUT | *furn_eq* | 8689 | 9006 | *publ_tran* | 3464 | 3548 |
| AUT | *health* | 5606 | 5816 | *rents* | 26759 | 27596 |
| AUT | *comm* | 3479 | 3294 | *vehicles* | 5885 | 5599 |
| AUT | *recr_acc* | 24742 | 25370 | *appliances* | 1659 | 1732 |
| AUT | *fin_serv* | 7221 | 7110 | *gfcf_houses* | 9364 | 10326 |
| AUT | *other* | 23375 | 24194 | | | |

For the variables for which official statistics do not contain data we have to use some assumptions in order to assign the base year values. Mostly, such assumptions are related to the bridge matrices between COICOP and CPA (the methods used to impute missing data include simple deduction by means of differences when possible, previous year structures when available, and closest structure according to the available data) as explained below.

Given the structure of the FIDELIO 3 model, a bridge matrix linking consumption expressed in COICOP terms (even though organised according to the variables of the model) and the CPA2008 commodities is needed. In order to achieve these bridge matrices, several steps were necessary. The COICOP vector for each country organised by consumption categories has been produced according to the description above. As for the CPA vector, data in PP are extracted from WIOD as explained in Subsection 4.1. Since it is possible that national total COICOP values coming from Eurostat do not match national CPA totals in WIOD, COICOP data have been occasionally adjusted to match this total, leaving the COICOP national structure unaltered.

Thus, it is necessary to build a bridge matrix between both vectors. The following strategy has been adopted in order to do so. For the following countries we started with some initial COICOP-CPA conversion matrices: Austria, Belgium, Czech Republic, Denmark,[32] Estonia, Finland, Germany, Portugal, Slovakia, Sweden, and the United Kingdom,[33] whose national statistical offices provided us with their own estimated COICOP-CPA conversion matrices. These matrices are quite heterogeneous in terms of product and COICOP breakdown and in some cases refer to years different from 2010. The Danish and German conversion matrices are expressed in BP. Hence, an initial harmonisation of these matrices was conducted to meet our desired level of disaggregation in terms of COICOP (15 categories) and CPA (56 products) and, when necessary, also conversion to PP.

Then, these matrices were commonly almost coincident to our COICOP vectors. In these cases, the resulting matrix directly becomes the final conversion matrix for these countries, inducing occasionally adjustments to the BP-PP conversion of the final consumption of households of the WIOD vector.

[32] For Denmark, tables are publicly available online at: https://www.dst.dk/ext/5198749172/0/inout/Excel-files-with-IO-data-for-the-period-2006-2015-(69-industries)--zip.

[33] For United Kingdom, tables are publicly available online at: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables.

For the rest of countries for which a prior matrix is not available, a balancing procedure was conducted. The above mentioned available matrices were used as proxies for the missing country priors. Also, the theoretical correspondence between CPA and COICOP classification was used as a potential prior. In the last case, where the convergence procedure was hard to achieve, a mixture between the selected prior and the theoretical correspondence was used.

In order to select a prior for a country from the set of available conversion matrices, several criteria were used. Based on the assumption that similar COICOP and/or WIOD structures would lead to similar conversion patterns, the proximity between the consumption vectors for the countries with no conversion matrix available and the countries with conversion matrices available was analysed using different metrics (SWAPE, SMAPE, and correlation coefficients). Countries with the most similar patterns of consumption were identified and then confronted with those resulting from other selection criteria such as GDP per capita similarity and geographical proximity. This led us to an initial choice for the prior matrix. In those cases where our set of criteria did not lead to a sound choice, the theoretical correspondence between CPA and COICOP classification was used as a prior.

In a subsequent step, the internal consistency of the chosen prior matrix was analysed in terms of its compatibility with the COICOP and the WIOD data. This process permitted to highlight several internal inconsistencies between the consumption values available in the COICOP vector and the WIOD vector. It is possible to find several groups of categories where the COICOP structure and WIOD structure link can be considered a one-to-one relationship. For instance, it is quite common that in most of the priors that the transport services category (CP073) in FIDELIO 3 and the transport categories in the CPA vector (H49, H50 and H51 according to the CPA classification) are linked. Hence the subtotals for these categories in the WIOD vector and the COICOP vector must match, and the balancing procedure would only work in estimating the internal breakdown for these categories in the CPA product dimension, leaving the aggregated subtotal unchanged. It is quite common that these subtotals do not match, which makes convergence impossible. In these situations we had to opt to modify the value of the subtotal either in the COICOP vector or in the WIOD vector. In general, the value closest to the original source (i.e. the value with fewer transformations undergone in the process) was usually kept, and the other one was modified accordingly. These decisions have led to posterior refinements in the BP-PP conversion of the WIOD final consumption of household vectors, or in the estimation of the COICOP vectors substructures when the available information was not enough to match the 14 categories of FIDELIO 3.

In other situations, the chosen prior matrix was combined with the theoretical correspondence between COICOP and CPA categories matrix to build a mixture prior. This was the case when target vectors of COICOP and WIOD showed values for products and categories of products, and the prior matrix showed no correspondences at all among them, or when convergence problems induced large changes in the COICOP and WIOD vectors which were not fully justified according to the reliability of both vectors.

In the end, 35 COICOP-CPA conversion matrices have been built, one for every country in the database of the FIDELIO 3 model, according to the base year 2010 figures. This process has led, as mentioned above, to several additional modifications of the COICOP and WIOD Final Consumption Households targets for the sake of coherence and convergence of the balancing procedure. These modifications in the COICOP target vectors are mostly negligible, and in the worst cases, the final target vectors structure differs in less than a 5% of the original target vector structure. These changes have generally contributed more to modify and refine our initial imputations methods of missing data, better than changing official figures from OECD or Eurostat, when available. Regarding the WIOD Final Consumption of Households vectors, the size of changes in terms of importance are aligned to the size of the described COICOP changes, however these changes have contributed to improve the change of valuation process in terms of coherence.

Table 19 below shows as an example how food consumption is translated to the NACE Rev. 2 commodities in the case of Austria.

**Table 19 Austrian bridge to NACE Rev. 2 for food consumption**

| R | G | food |
|---|---|---|
| AUT | CPA_A01 | 0.12177 |
| AUT | CPA_A02 | 0.00000 |
| AUT | CPA_A03 | 0.00477 |
| AUT | CPA_B | 0.00000 |
| AUT | CPA_C10-C12 | 0.87346 |

### 4.2.3 Household stocks

Household vehicles and housing stock data are scarce and it proved impossible to find a unique data source capable of providing data for a substantial number of countries and at the same time ensuring a certain consistency in the values. Thus, a decision was taken to assume the value of the stocks depending on the flow variables related to them. Based on the depreciation rates used for FIDELIO 2, the following assumptions were made:

- Stock of appliances = $1.00/0.07 = 14.29$ times the yearly expenditure for appliances;
- Stock of vehicles = $1.00/0.08 = 12.50$ times the yearly expenditure for vehicles;
- Stock of houses = $1.00/0.015 = 66.67$ times the yearly rents.

Although this procedure can certainly be seen as ad hoc, and numbers can be questioned, we stand ready to modify the numbers resulting from it should actual data become available. Also, the advantage of such a simple set of assumptions is that it can be easily modified should we acquire reliable information on the stock-flow relationships for such variables.

A series of stock variables are used in FIDELIO 3. As per equations (38) and (39), the net wealth of households (made by financial assets and liabilities) is used and its data come from the Eurostat dataset (nasa_10_f_bs) "Financial balance sheets of households and non-profit institutions serving households" for the EU28 countries, and from the OECD dataset (no. 710) "Financial balance sheets - consolidated". The 2010 stocks of own housing and vehicles are calculated as their yearly consumption in 2010 divided by the assumed depreciation rates (0.015 and 0.08, respectively). Then, the stocks move according to equations (47) and (48). Finally, cash-in-hands is calculated as the sum of disposable income, net wealth, and durable stocks as per equation (38).

## 4.3 The rest of the data: the government block

Both governmental revenues and expenditures are featured in the model. The main source of this type of data not already taken from WIOD is the Eurostat dataset (nasa_10_nf_tr) "Non-financial transactions" of the government for the EU28 countries, and the OECD governmental accounts for the non-EU countries.

Operating surplus is B2A3G (operating surplus and mixed income, gross) accruing to the government, and the base year value is taken from Eurostat data. In the model, as per equation (65), it is assumed to be equal to the base year proportion of total operating surplus (coming from the IO VA data).[34] Taxes less subsidies come from the IO dataset. Taxes on production and employer social security contributions correspond to D29X39 and D12, respectively, from the IO VA data. Employee social security contributions are the same appearing in the household block as explained above. The same goes for taxes on income and wealth, that is the *YDTaxesHH* variable of the household block, equation (43). The sum of these revenues is collected in the total revenues variable according to equation (64).

As for the spending side, government consumption comes from the IO dataset. The interests paid on public debt come from the Eurostat table gov_10a_main (interest, payable).[35] Public investment data also come from that same Eurostat dataset. Missing data are filled using the sample average proportion of public investment with respect to government consumption to mimic equation (73). Governmental transfers correspond to the sum of governmental transfers and other transfers to households already introduced in equation (41) whose data come from Eurostat as explained in Subsection 4.2.1 above. All these expenditures are summed into government total expenditure.

Then, the budget balance is calculated according to equation (76). The 2010 value of this variable is calculated directly into the model using base year data for all revenues and expenditures. A correction factor is used when government consumption is endogenised so to make sure that the values match with the data for the ratio between the budget balance and GDP. The latter ratio is exogenous when government consumption is endogenised, and it is assumed to go to zero (that is, it is assumed that all countries achieve a balanced budget) in 2020.

Finally, governments accumulate public debt, whose base year data correspond to GD (government consolidated gross debt) in the Eurostat dataset (gov_10dd_edpt1) "Government deficit/surplus, debt and associated data". Data for Turkey come from the OECD dataset (no. 750) "General government debt - Maastricht". Data for the rest of the countries are taken from the World Bank. Table 20 below contains the base year values of the governmental variables for Austria, Belgium and Bulgaria to illustrate the data.

**Table 20 Values of the governmental variables for the base year for three countries**

| Variables | AUT | BEL | BGR |
|---|---|---|---|
| *GovOpSur* | 7986.6 | 8024.7 | 2126.7 |
| *GovTlS* | 32309.7 | 38706.6 | 9829.8 |
| *GovProdTax* | 3945.8 | -1662.4 | -920.0 |

[34] For the countries for which there are no data, the sample average (7%) is assumed.
[35] Once again, the sample average of the rate of interest paid over debt is used to fill the cells for the countries for which data are missing.

| | | | |
|---|---|---|---|
| *YDTaxesHH* | 31098.5 | 45823.3 | 2093.0 |
| $YDSSec^{employer}$ | 24286.7 | 50383.3 | 3967.5 |
| $YDSSec^{employee}$ | 23159.0 | 23599.4 | 24214.6 |
| *GovInterest* | 8544.9 | 13199.3 | 531.6 |
| *YDTran* | 59194.0 | 69839.0 | 8950.0 |
| *YDOtherTran* | 2380.0 | 1824.0 | 1678.0 |
| *Govgfcf* | 9607.4 | 8428.3 | 3428.9 |
| *GovCons* | 60011.5 | 86308.6 | 11690.5 |
| *GovDebt* | 243773.7 | 364751.5 | 11692.8 |

## 4.4 The rest of the data: the labour market

Employment by country and industry is taken from the WIOD social accounts. The unemployment rates used for the base year are shown in Table 21 below and come from Eurostat for the European countries and from the World Bank for the non-European ones.

**Table 21 Base year unemployment rates**

| R | *unempRate* | R | *unempRate* | R | *unempRate* | R | *unempRate* |
|---|---|---|---|---|---|---|---|
| AUT | 0.047 | EST | 0.167 | JPN | 0.050 | RUS | 0.073 |
| BEL | 0.082 | FIN | 0.083 | LVA | 0.195 | SVK | 0.143 |
| BRA | 0.067 | FRA | 0.089 | LTU | 0.178 | SVN | 0.072 |
| BGR | 0.089 | DEU | 0.064 | LUX | 0.048 | ESP | 0.191 |
| CHN | 0.029 | GRC | 0.120 | MLT | 0.068 | SWE | 0.086 |
| HRV | 0.115 | HUN | 0.112 | NLD | 0.048 | TUR | 0.109 |
| CYP | 0.060 | IND | 0.035 | POL | 0.096 | GBR | 0.078 |
| CZE | 0.071 | IRL | 0.139 | PRT | 0.116 | USA | 0.096 |
| DEN | 0.074 | ITA | 0.078 | ROU | 0.064 | | |

The base year labour supply (by region and labour skill) is calculated using data on employment and unemployment rate as per equation (91). The skill-specific labour force participation rates are calculated using CEDEFOP data, population data and the labour supply as per equation (92). As for the non-European countries, German rates are used to calculate the labour supply rates for Japan and the USA, and Romanian ones are used for the rest (rates are rescaled in order to match the actual labour supply numbers). Numbers for the first eight countries of the sample are contained in Table 22 below.

**Table 22 Labour supply rates for eight countries**

| **Country** | *LSupplyRate("low")* | *LSupplyRate("medium")* | *LSupplyRate("high")* |
|---|---|---|---|
| AUT | 0.086 | 0.329 | 0.098 |
| BEL | 0.100 | 0.173 | 0.173 |
| BGR | 0.080 | 0.326 | 0.139 |
| BRA | 0.132 | 0.319 | 0.084 |
| CHN | 0.149 | 0.359 | 0.095 |
| CYP | 0.092 | 0.149 | 0.146 |
| CZE | 0.031 | 0.396 | 0.091 |
| DEN | 0.142 | 0.229 | 0.166 |

In the absence of data, the wage shares by skill are simply calculated so to be equal to the employment shares: that is, if 20% of the employed are low-skill workers, then the base year low skill's wage share is equal to 0.20.

## 4.5 The rest of the data: the energy block

The exogenous prices of electricity, fuel and heating used in the household block in equations (54), (55), and (56) are taken from the POLES model. Three scenarios are available, the default in FIDELIO being the first one: reference, INDCs, and 2 degrees. The final user prices for buildings (electricity, average price for heating, and road transport gasoline prices) are used. As for the calculation of the exogenous price of the energy input used in equation (95), the POLES final user prices of the industry are used for the five energy carriers: coal, oil, gas, renewables (biomass prices are used), and electricity and heating (electricity prices are used). Table 23 contains the 2010-2015 prices for Austria (reference scenario) to illustrate the data format.

**Table 23 Austrian energy prices 2010-2015**

| R | Price | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| AUT | *PElec* | 1.00 | 0.98 | 0.96 | 0.98 | 0.94 | 0.93 |
| AUT | *PFuel* | 1.00 | 1.11 | 1.15 | 1.08 | 1.03 | 0.91 |
| AUT | *PHeat* | 1.00 | 1.04 | 1.07 | 1.04 | 1.01 | 0.96 |
| AUT | *PCoal* | 1.00 | 1.09 | 1.17 | 1.01 | 0.91 | 0.89 |
| AUT | *POil* | 1.00 | 1.22 | 1.34 | 1.18 | 1.09 | 0.70 |
| AUT | *PGas* | 1.00 | 1.01 | 1.16 | 1.16 | 1.09 | 1.03 |
| AUT | *PRenew* | 1.00 | 1.15 | 1.24 | 1.08 | 0.99 | 0.81 |
| AUT | *PElHeat* | 1.00 | 0.97 | 0.93 | 0.91 | 0.86 | 0.83 |

$CO_2$, $CH_4$, and $N_2O$ emissions in tonne by region and by industry are taken from the env_ac_ainah_r2 dataset published by Eurostat.

The energy uses expressed in physical units (TJ) are estimated by the ELIOD[36] project. The deliverable 6 of the ELIOD project estimated the energy uses in physical units for the period 2010-2014 and for EU-28 Member States, USA and Japan. The series are consistent with NACE Rev.2 classification.

The estimates of energy uses are based on the methodology developed by Genty et al. (2012) for the first edition of the WIOD Energy Accounts. The methodology implied that, whenever available, official energy use accounts were used as main data source (mainly occurring for countries such as Austria, Germany, Netherlands and Denmark). However, as national data were not available for all countries/years/industries/commodities, the energy accounts were estimated using the information from the energy balances of the International Energy Agency (IEA) further disaggregated/reallocated using the monetary information from the Supply and Use Tables of WIOD, and complemented with information on fuel prices (IEA), on car shares (ODYSSEE database), on international bunkering (EXIOPOL database) and on employment (KLEMS database).

[36] Environmental and Labour accounts linked to a global Input-Output Database.

The estimation implied:

- a redefinition of the industrial boundaries through a technical redistribution of energy uses that reflects the energy mix of countries and
- a correction for the geographical mismatch between the territorial principle (on which energy balances are based) and the residence principle (on which energy accounts are based).

The resulting energy use tables represent an equivalent Use tables for energy products in physical terms; it contains the energy products that are consumed by the intermediate consumption and households within the national territory. The main concept covered is the gross energy use, which includes the energy intermediate consumption of energy by industries and allows answering questions related to the energy mix and to the substitution of energy inputs in electricity production over time. The gross energy use is fully consistent with the National Accounts framework on which WIOD is based.

The Energy Use tables take the form of matrices of entries by country, by industry, by energy commodity and by year.

- The geographical coverage has been recently increased to 43 WIOD countries.
- The industrial coverage is the same as the WIOD's Use tables in monetary terms, i.e. 64 NACE Rev. 2 industries.
- The energy commodity coverage is reduced to 11 from the 26 carriers present for the first edition of the WIOD Energy Accounts (see Annex 12).

Table 24 illustrates the 2010 Austrian energy uses for selected industries.

**Table 24 Austrian gross energy use by energy commodities for selected industries (TJ)**

| | DIESEL | GASOLINE | JETFUEL | OTHGAS | WASTE | COAL, COKE , CRUDE | FUEL OIL | LIQUID GASEOUS BIOFUELS | ELECTR, HEATPROD | RENEWABLES NUCLEAR | NATGAS LPG, OTHPETR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A01 | 9.32 | - | - | - | - | 0.05 | 0.36 | 0.76 | 4.66 | 6.09 | 0.68 | 21.92 |
| A02 | - | - | - | - | - | - | - | 0.10 | - | 0.00 | 0.00 | 0.11 |
| A03 | - | - | - | - | - | - | - | 0.00 | - | - | 0.00 | 0.00 |
| B | 2.73 | 0.01 | - | - | - | 0.00 | 0.24 | 0.02 | 4.74 | 0.02 | 5.99 | 13.75 |
| C10_12 | 2.77 | 0.07 | - | - | 0.01 | 0.16 | 2.36 | 0.15 | 8.69 | 0.30 | 12.86 | 27.37 |
| C13_15 | 0.14 | 0.02 | - | - | - | - | 0.37 | 0.02 | 1.59 | 0.04 | 1.87 | 4.06 |
| C16 | 2.54 | 0.03 | - | - | 0.69 | - | 0.30 | 0.03 | 7.85 | 14.94 | 3.03 | 29.40 |

The energy use in physical terms together with energy expressed in monetary terms serves for the calculation of the inverse of energy price $IO\_EnergyTJ_{2010}$ in equation (96). It also feeds into the disaggregation of the energy consumption over 11 carriers (equation 97).

ELIOD energy and emission accounts are expected to be published in 2019.

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# Annexes

### Annex 1 List of sets in FIDELIO

| Set | Description |
|---|---|
| aC (aU) | "All Category": Components of final demand |
| aU | "All Users": Economic agents in supply-use-scheme (industries plus final demand) |
| CPC | "CP Commodity Groups": Commodities in private consumption block |
| CPEn (CPC) | "CP Energy Commodities": Energy goods in private consumption block |
| eG (G) | "Energy Good": Energy commodities |
| EnC | "Energy Carriers": Five main energy carriers and total energy |
| EnCcalc (EnC) | "Energy Carriers Calculation": Five main energy carriers |
| EnCd | "Energy Carriers _detail": Eleven energy carriers |
| G | "Good": Commodities in the supply-use-scheme (2-digit NACE labels) |
| LS | "Labour Skills": three labour skill levels (low, medium, and high) and total labour |
| LSca (LS) | "Labour Skills Calculation": three labour skill levels |
| neG (G) | "Non-Energy Good": Non-energy commodities |
| nTIR (G) | "Non-TIR": Goods and services NOT used in international trade and transport TIR |
| QC (CPC) | "QAIDS Commodity": Commodities included in QAIDS-model |
| R (WR) | "Region": Countries modelled in FIDELIO (EU28 + 7 nonEU) |
| S (aU) | "Sector": Industries in the supply-use-scheme ("aU" without final demand) |
| TIRS (G) | "TIR Services": Services used in international trade and transport (TIR) |
| VAC | "VA Components": Components of value added |
| WR | "World region": Countries in FIDELIO (EU28 + 7 nonEU + ROW as a residual) |

Note: The table lists both sets and sub-sets.for sub-sets, the respective set is specified in parenthesis

**Annex 2 List of NACE Rev. 2 industries in FIDELIO**

| Sector | Description |
|---|---|
| A01 | Crop and animal production, hunting and related service activities |
| A02 | Forestry and logging |
| A03 | Fishing and aquaculture |
| B | Mining and quarrying |
| C10T12 | Manufacture of food products, beverages and tobacco products |
| C13T15 | Manufacture of textiles, wearing apparel and leather products |
| C16 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials |
| C17 | Manufacture of paper and paper products |
| C18 | Printing and reproduction of recorded media |
| C19 | Manufacture of coke and refined petroleum products |
| C20 | Manufacture of chemicals and chemical products |
| C21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations |
| C22 | Manufacture of rubber and plastic products |
| C23 | Manufacture of other non-metallic mineral products |
| C24 | Manufacture of basic metals |
| C25 | Manufacture of fabricated metal products, except machinery and equipment |
| C26 | Manufacture of computer, electronic and optical products |
| C27 | Manufacture of electrical equipment |
| C28 | Manufacture of machinery and equipment n.e.c. |
| C29 | Manufacture of motor vehicles, trailers and semi-trailers |
| C30 | Manufacture of other transport equipment |
| C31_32 | Manufacture of furniture; other manufacturing |
| C33 | Repair and installation of machinery and equipment |
| D35 | Electricity, gas, steam and air conditioning supply |
| E36 | Water collection, treatment and supply |
| E37T39 | Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services |
| F | Construction |
| G45 | Wholesale and retail trade and repair of motor vehicles and motorcycles |
| G46 | Wholesale trade, except of motor vehicles and motorcycles |
| G47 | Retail trade, except of motor vehicles and motorcycles |
| H49 | Land transport and transport via pipelines |
| H50 | Water transport |
| H51 | Air transport |
| H52 | Warehousing and support activities for transportation |
| H53 | Postal and courier activities |
| I | Accommodation; food and beverage service activities |
| J58 | Publishing activities |
| J59_60 | Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities |
| J61 | Telecommunications |
| J62_63 | Computer programming, consultancy and related activities; information service activities |
| K64 | Financial service activities, except insurance and pension funding |
| K65 | Insurance, reinsurance and pension funding, except compulsory social security |
| K66 | Activities auxiliary to financial services and insurance activities |
| L68 | Real estate activities |
| M69_70 | Legal and accounting activities; activities of head offices; management consultancy activities |
| M71 | Architectural and engineering activities; technical testing and analysis |
| M72 | Scientific research and development |
| M73 | Advertising and market research |
| M74_75 | Other professional, scientific and technical activities; veterinary activities |
| N | Administrative and support service activities |
| O84 | Public administration and defence; compulsory social security |

**Annex 2 List of NACE Rev. 2 industries in FIDELIO (cont'd)**

| Sector | Description |
|---|---|
| P85 | Education |
| Q | Human health and social work activities |
| R-S | Arts, entertainment and recreation. Other service activities |
| T | Activities of households as employers; undifferentiated goods and services producing activities of households for own use |
| U | Activities of extraterritorial organisations and bodies |

**Annex 3 List of CPA 2008 products in FIDELIO**

| Good | Description |
|---|---|
| CPA_A01 | Products of agriculture, hunting and related services |
| CPA_A02 | Products of forestry, logging and related services |
| CPA_A03 | Fish and other fishing products; aquaculture products; support services to fishing |
| CPA_B | Mining and quarrying |
| CPA_C10-C12 | Food products; Beverages; Tobacco products |
| CPA_C13-C15 | Textiles; Wearing apparel; Leather and related products |
| CPA_C16 | Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials |
| CPA_C17 | Paper and paper products |
| CPA_C18 | Printing and recording services |
| CPA_C19 | Coke and refined petroleum products |
| CPA_C20 | Chemicals and chemical products |
| CPA_C21 | Basic pharmaceutical products and pharmaceutical preparations |
| CPA_C22 | Rubber and plastic products |
| CPA_C23 | Other non-metallic mineral products |
| CPA_C24 | Basic metals |
| CPA_C25 | Fabricated metal products, except machinery and equipment |
| CPA_C26 | Computer, electronic and optical products |
| CPA_C27 | Electrical equipment |
| CPA_C28 | Machinery and equipment n.e.c. |
| CPA_C29 | Motor vehicles, trailers and semi-trailers |
| CPA_C30 | Other transport equipment |
| CPA_C31_C32 | Furniture; Other manufactured goods |
| CPA_C33 | Repair and installation services of machinery and equipment |
| CPA_D35 | Electricity, gas, steam and air conditioning |
| CPA_E36 | Natural water; water treatment and supply services |
| CPA_E37-E39 | Sewerage services; sewage sludge; Waste collection, treatment and disposal services; materials recovery services; Remediation services and other waste management services |
| CPA_F | Construction and construction works |
| CPA_G45 | Wholesale and retail trade and repair services of motor vehicles and motorcycles |
| CPA_G46 | Wholesale trade services, except of motor vehicles and motorcycles |
| CPA_G47 | Retail trade services, except of motor vehicles and motorcycles |
| CPA_H49 | Land transport services and transport services via pipelines |
| CPA_H50 | Water transport services |
| CPA_H51 | Air transport services |
| CPA_H52 | Warehousing and support services for transportation |
| CPA_H53 | Postal and courier services |
| CPA_I | Accommodation and food services |
| CPA_J58 | Publishing services |
| CPA_J59_J60 | Motion picture, video and television programme production services, sound recording and music publishing; Programming and broadcasting services |
| CPA_J61 | Telecommunications services |
| CPA_J62_J63 | Computer programming, consultancy and related services; Information services |
| CPA_K64 | Financial services, except insurance and pension funding |
| CPA_K65 | Insurance, reinsurance and pension funding services, except compulsory social security |
| CPA_K66 | Services auxiliary to financial services and insurance services |
| CPA_L68 | Real estate services |
| CPA_M69_M70 | Legal and accounting services; Services of head offices; management consulting services |
| CPA_M71 | Architectural and engineering services; technical testing and analysis services |
| CPA_M72 | Scientific research and development services |
| CPA_M73 | Advertising and market research services |
| CPA_M74_M75 | Other professional, scientific and technical services; Veterinary services |
| CPA_N | Administrative and support services |
| CPA_O84 | Public administration and defence services; compulsory social security services |

**Annex 3 List of CPA 2008 products in FIDELIO (cont'd)**

| Good | Description |
|---|---|
| CPA_P85 | Education services |
| CPA_Q | Human health and social work services |
| CPA_R_S | Arts, entertainment, recreation and other services |
| CPA_T | Services of households as employers |
| CPA_U | Services provided by extraterritorial organisations and bodies |

**Annex 4 List of FIDELIO private consumption products and corresponding COICOP goods**

| | Private consumption products | COICOP code | COICOP product |
|---|---|---|---|
| 1 | Food | CP01 | Food and non-alcoholic beverages |
| | | CO021 | Alcoholic beverages |
| 2 | Clothing | CP03 | Clothing and footwear |
| 3 | Furniture/equipment | CP051 | Furniture and furnishings |
| | | CP052 | Household textiles |
| | | CP054 | Glassware, tableware and household utensils |
| | | CP055 | Tools and equipment for house and garden |
| | | CP056 | Goods and services - household maintenance |
| 4 | Health | CP06 | Health |
| 5 | Communication | CP08 | Communications |
| 6 | Recreation, accommodation | CP094 | Recreational and cultural services |
| | | CP111 | Catering services |
| | | CP112 | Accommodation services |
| 7 | Financial services | CP125 | Insurance |
| | | CP126 | Financial services n.e.c. |
| 8 | Imputed rent | CP042 | Imputed rentals for housing |
| 9 | Electricity/heating | CP45 | Electricity, gas and other fuels |
| 10 | Appliances | CP053 | Household appliances |
| 11 | Vehicles | CP071 | Purchase of vehicles |
| 12 | Private transport | CP072 | Operation of personal transport equipment |
| 13 | Public transport | CP073 | Transport services |
| 14 | Other | CP09 (no CP094) | Recreation and culture except services |
| | | CP10 | Education |
| | | CP12 (no CP125&CP126) | Restaurants and hotels |
| | | CP022 | Tobacco |
| | | CP023 | Narcotics |

**Annex 5 FIDELIO endogenous variables**

| Variable | Description |
|---|---|
| $Capital(R,S)$ | Sectoral demand for capital |
| $CashHH(R)$ | Household cash-in-hands |
| $CPComm(R,"Appl")$ | Household consumption of appliances |
| $CPComm(R,CPC)$ | Household consumption by commodity group (CPC categories) |
| $CPComm(R,"Elec")$ | Household consumption of electricity |
| $CPComm(R,"Energy")$ | Household consumption of energy services |
| $CPComm(R,"Fuel")$ | Household consumption of fuel |
| $CPComm(R,"Heat")$ | Household consumption of heating |
| $CPComm(R,"NonDur")$ | Household total non-durables durable consumption |
| $CPComm(R,"PubTran")$ | Household consumption of public transport services |
| $CPComm(R,"Rents")$ | Household durables consumption related to houses |
| $CPComm(R,"Tot")$ | Household total consumption |
| $CPComm(R,"TotDur")$ | Household total durables consumption |
| $CPComm("Tran")$ | Household consumption of transport |
| $CPComm(R,"Veh")$ | Household durables consumption related to vehicles |
| $CPgfcf\_housing(R)$ | Household expenditure in houses |
| $CPQAIDS(R)$ | Household consumption in food, clothing, furniture and equipment, health, communication, recreation and accommodation, financial services, and other (QAIDS products) |
| $Em\_CH4(R,S)$ | Sectoral $CH_4$ emissions related to production |
| $Em\_CO2(R,S,EnCd)$ | Sectoral $CO_2$ emissions related to energy consumption |
| $Em\_CO2HH(R,EnCd)$ | $CO_2$ household emissions by region and by detailed energy carrier |
| $Em\_N2O(R,S)$ | Sectoral $N_2O$ emissions related to production |
| $Empl(R,S,LS)$ | Employment |
| $Energy(R,S)$ | Sectoral demand for energy intermediates |
| $EnergyTJ(R,S)$ | Sectoral demand for energy in TJ |
| $EnergyTJHH(R,S)$ | Household demand for energy in TJ |
| $G\_BP(R,G,aU)$ | Demand for domestic and imported products in basic prices |
| $G\_PP(R,G,aU)$ | Demand for commodities in purchaser prices |
| $G\_PP(R,G,"CP")$ | Household demand for commodities |
| $G\_PP(R,G,"CG")$ | Government demand for commodities |
| $G\_PP(R,G,"Inv")$ | Investment demand for commodities |
| $G\_PP(R,G,"Inventory")$ | Demand for inventories |
| $G\_PP(R,G,"NPISH")$ | NPISH demand for commodities |
| $GD\_BP(R,G,aU)$ | Demand for domestically produced goods by each user |
| $GDP(R)$ | Gross domestic product |
| $GDtot(R,G)$ | Total demand for domestically produced goods |
| $GovBdgt(R)$ | Government budget balance |
| $GovCons(R)$ | Government consumption |
| $GovDebt(R)$ | Government debt |
| $Govgfcf(R)$ | Government capital formation |
| $GovInterest(R)$ | Interests paid by the government |
| $GovOpSur(R)$ | Share of gross operating surplus going to the government |
| $GovProdTax(R)$ | Production taxes paid by firms to the government |
| $GovTlS(R)$ | Taxes less subsidies paid by firms to the government |
| $GovTotExp(R)$ | Government total expenditure |
| $GovTotRev(R)$ | Governmental total revenues |
| $I\_PP\_GOP(R,S)$ | Sectoral investment computed from gross operating surplus |
| $I\_PP\_KStock(R,S)$ | Sectoral investment computed from capital stock |
| $I\_PP\_Q(R,S)$ | Sectoral investment computed from output |
| $InputFuel(R,S,EnCd)$ | Sectoral demand or energy carriers |
| $KAppl(R)$ | Household stock of appliances |
| $KHous(R)$ | Household stock of houses |
| $KLE\_Q(R,S)$ | KLE share in the first CES nest level |

**Annex 5 FIDELIO endogenous variables** (cont'd)

| Variable | Description |
|---|---|
| $KStock(R,S)$ | Capital stock |
| $KVehicles(R)$ | Household stock of vehicles |
| $Labour(R,S)$ | Sectoral demand for labour |
| $LSupply(R,LS)$ | Labour supply |
| $M(R,G,aU)$ | Demand for imports in CIF prices |
| $Materials(R,S)$ | Sectoral demand for materials |
| $MShare(R,G,aU)$ | Share of import over total demand |
| $Mtot(R,G)$ | Total import by region and good |
| $NetWorthHH(R)$ | Household financial assets |
| $NPISH(R)$ | Consumption of non-profit institutions serving households |
| $P\_KLE(R,S)$ | Price of combined capital, energy, and labour inputs |
| $P\_SM(R,S)$ | Price of the materials |
| $PAppl(R)$ | Price of appliances |
| $PComm(R,QC)$ | Price of the QAIDS products |
| $PComm(R,"Veh")$ | Price of private consumption by commodity group |
| $PCP(R)$ | Consumer price index |
| $PG(R,G)$ | Domestic commodity price excluding TTM and TlS |
| $PGdom(R,G,aU)$ | Domestic commodity price including TTM and TlS |
| $PGPartners(R,WR,G)$ | Price of imported products by trading partner (all countries) |
| $PGPatners(R,R1,G)$ | Price of imported products by trading partner (countries excluding ROW) |
| $PGPatners(R,"ROW",G)$ | Price of imported products by trading partner (only ROW) |
| $PInputs(R,S,"Capital")$ | Price of capital |
| $PInputs(R,S,"E")$ | Price of energy |
| $PInputs(R,S,"L")$ | Price of labour |
| $PL(R,S,LSca)$ | Wages |
| $PM(R,G,aU)$ | Import price including domestic margins and TlS |
| $PMcif(R,G)$ | Import price |
| $PQ(R,S)$ | Output price |
| $PTTM(R,aU)$ | Price of TTM |
| $PUse(R,G,aU)$ | Price of commodities |
| $Q(R,S)$ | Output by industry |
| $Qreal(R,S)$ | Real output by industry |
| $QAIDSShare(R,QC)$ | Shares of QAIDS commodities consumption |
| $SavHH(R)$ | Household savings |
| $SC\_Q(R,S)$ | Capital share in the second CES nest level |
| $SE\_Q(R,S)$ | Energy share in the second CES nest level |
| $SL\_Q(R,S)$ | Labour share in the second CES nest level |
| $SM\_Q(R,S)$ | Materials share in the first CES nest level |
| $TIRMatrix(R,WR,nTIR)$ | Matrix of international trade and transport margins (nTIR products) |
| $TIRMatrix(R,WR,TIRS)$ | Matrix of international trade and transport margins (TIRS products) |
| $TlS(R,G,aU)$ | Taxes less subsidies |
| $TradeMatrix(R,WR,nTIR)$ | Trade matrix by trading partner related to nTIR commodities |
| $TradeMatrix(R,WR,TIRS)$ | Trade matrix by trading partner related to TIRS commodities |
| $TradeShares(R,WR,G)$ | Import shares matrix by trading partner |
| $TTMpaid(R,G,aU)$ | Transport and trade margins paid |
| $TTMrec(R,G,aU)$ | Transport and trade margins received |
| $UnempRate(R,LS)$ | Unemployment rate |
| $VA(R,S)$ | Sectoral value added |
| $VAblocks(R,S,"Depr")$ | Sectoral depreciation |
| $VAblocks(R,S,"OpSur")$ | Sectoral net operating surplus |
| $VAblocks(R,S,"ProdTax")$ | Sectoral production taxes |
| $VAblocks(R,S,"SocSec")$ | Sectoral social security contribution |
| $VAblocks(R,S,"Wages")$ | Sectoral wages |
| $YD(R)$ | Household disposable income |

**Annex 5 FIDELIO endogenous variables** **(cont'd)**

| Variable | Description |
|---|---|
| $YDOpSurHH(R)$ | Share of gross operating surplus going to households |
| $YDSSec^{employee}(R)$ | Social security contributions paid by workers |
| $YDSSec^{employer}(R)$ | Social security contributions paid by firms |
| $YDTaxesHH(R)$ | Taxes paid by households to the government |
| $YDTran(R)$ | Transfers paid by the government to households |
| $YDOtherTran(R)$ | Other transfers paid to households |

**Annex 6 FIDELIO exogenous variables**

| Variable | Description |
|---|---|
| $Eff\_Appl(R)$ | Exogenous index capturing the efficiency of appliances |
| $Eff\_Heat(R)$ | Exogenous index capturing the efficiency of heating |
| $Eff\_Veh(R)$ | Exogenous index capturing the efficiency of vehicles |
| $PCPEnergy(R, CPEn)$ | Price of energy consumed by households |
| $PElec(R)$ | Price of electricity |
| $PFuel(R)$ | Price of fuel |
| $PHeat(R)$ | Price of heating |
| $PInputs(R, S, "E")$ | Price of energy |
| $Pop(R)$ | Population |
| $RealEnShares(R, S, EnC)$ | Exogenous shares of the 5 main energy carriers |

**Annex 7 2010 data used to calibrate the FIDELIO parameters**

| Parameter | Description |
|---|---|
| $CPComm_{2010}(R,"Fuel")$ | Household consumption of fuel |
| $CPComm_{2010}(R,"PubTran")$ | Household consumption of public transport |
| $GovIntRate_{2010}(R)$ | Interest rate paid by the government on the debt |
| $IO\_M_{2010}(R,G,aU)$ | Imports by user in CIF prices |
| $IO\_Make_{2010}(R,G,S)$ | Make matrix |
| $IO\_NPISH_{2010}(R,G)$ | Consumption of non-profit institutions serving households |
| $IO\_UseBP_{2010}(R,G,aU)$ | Total use by user in basic prices |
| $IO\_Use\_PP_{2010}(R,G,S)$ | Total use by industry in purchaser prices |
| $Inventory\_PP_{2010}(R,G)$ | Commodity demand for inventories |
| $InvMatrix_{2010}(R,G,S)$ | Matrix of investment by country, good, and industry |
| $Labour_{2010}(R,S)$ | Sectoral labour cost |
| $NumberHH(R)$ | Number of households |
| $Q_{2010}(R,S)$ | Sectoral output |
| $VAblocks_{2010}(R,S,\text{"Wages"})$ | Sectoral wages |
| $VAblocks_{2010}(R,S,\text{"SocSec"})$ | Sectoral social security contribution |
| $VAblocks_{2010}(R,S,"ProdTax")$ | Sectoral production taxes |
| $VAblocks_{2010}(R,S,"Depr")$ | Sectoral depreciation |
| $XRate_{2010}(R)$ | Exchange rates from WIOD |
| $XRow_{2010}(R,G)$ | Export to the rest of the world |
| $YDSSec_{2010}^{employee}$(R) | Social security contributions paid by workers |
| $HeatDDay_{2010}(R)$ | Measurement of heating degree days |
| $VehPop_{2010}(R)$ | Average number of vehicles per person |

**Annex 8 FIDELIO calibrated parameters from 2010 data**

| Parameter | Description |
|---|---|
| $\alpha^{C}(R,S)$ | Relative share of capital in the second CES nest |
| $\alpha^{L}(R,S)$ | Relative share of labour in the second CES nest |
| $\alpha^{E}(R,S)$ | Relative share of energy in the second CES nest |
| $\alpha^{M}(R,S)$ | Relative share of materials in the first CES nest |
| $\alpha^{KLE}(R,S)$ | Relative share of the KLE bundle in the first CES nest |
| $CPBridge_{2010}(R,G,CPC)$ | Bridge matrix from CPC consumption categories to NACE Rev. 2 consumption classification |
| $Bridge\_EnCd_{2010}(R,S,EnC,EnCd)$ | Bridge matrix from 5 to 11 sectoral energy carriers |
| $Bridge\_EnCdHH_{2010}(R,CPEn,EnCd)$ | Bridge matrix from 3 household energy commodities to 11 energy carriers |
| $BPStruct_{2010}(R,G)$ | Proportion of BP over BP plus TTM |
| $GovSharegfcf_{2010}(R)$ | Proportion of public investment over public consumption |
| $IO\_CommTlS_{2010}(R,G,aU)$ | Proportion of taxes less subsidies over the use value in basic prices plus trade and transport margins |
| $IO\_EnergyTJ_{2010}(R,S)$ | Inverse of the price of energy for sectoral consumption |
| $IO\_EnergyTJHH_{2010}(R,CPEn)$ | Inverse of the price of energy for household consumption |
| $IO\_GovConsVA_{2010}(R)$ | Proportion of government consumption over total VA |
| $IO\_GovShOp_{2010}(R)$ | Proportion of government operating surplus over gross operating surplus |
| $IO\_HHShOp_{2010}(R)$ | Proportion of household operating surplus over gross operating surplus |
| $IO\_I\_GOP_{2010}(R,S)$ | Proportion of investment over gross operating surplus |
| $IO\_I\_Q_{2010}(R,S)$ | Proportion of investment over output |
| $IO\_ProdTaxQ_{2010}(R,S)$ | Proportion of production taxes over output Q |
| $IO\_Tax\_Inc_{2010}(R)$ | Ratio of household income taxes over income |
| $IOEm\_CH4_{2010}(R,S)$ | $CH_4$missions coefficient per sectoral unit of output |
| $IOEm\_CO2_{2010}(R,S,EnCd)$ | $CO_2$missions coefficient per sectoral energy inputs used |
| $IOEm\_CO2HH_{2010}(R,EnCd)$ | $CO_2$missions coefficient per household energy use |
| $IOEm\_N2O_{2010}(R,S)$ | $N_2O$missions coefficient per sectoral unit of output |
| $IStruct_{2010}(R,G,S)$ | Commodity investment structure by industry |
| $LSupplyRate_{2010}(R,LS)$ | Participation rate by skill level |
| $MktShares^{make}_{2010}(R,G,S)$ | Sector shares in output of any good |
| $MrgPaid_{2010}(R,G,aU)$ | Trade and transport margins as a share of use (PP) minus taxes less subsidies |
| $MrgRec_{2010}(R,G,aU)$ | Share of TTM received over the total TTM paid |
| $OpSurHH\_G_{2010}(R)$ | Share of operating surplus that goes to households |
| $Rent\_Houses_{2010}(R)$ | Ratio of rents over housing stock |
| $SE\_Q_{2010}(R,S)$ | Share of energy intermediates over sectoral production |
| $SL\_Q_{2010}(R,S)$ | Share of labour over sectoral production |
| $SkillShares_{2010}(R,S,LSca)$ | Shares of skill groups |
| $SM\_Q_{2010}(R,S)$ | Share of material intermediates over sectoral production |
| $S\_Q_{2010}(R,S)$ | Share of total intermediate inputs over sectoral production |
| $SC\_Q_{2010}(R,S)$ | Share of capital over sectoral production |
| $TradeShares_{2010}(R,WR,G)$ | Import share by trading partner |
| $TIRShares_{2010}(R,WR,nTIRS,TIRS)$ | Transport cost distribution over TIRS commodities |
| $TransitCost_{2010}(R,WR,nTIR)$ | International trade and transport margins expressed as % over imports in FOB |
| $TTMStruct_{2010}(R,G,aU)$ | Proportion of TTM over BP plus TTM |
| $UseStruct_{2010}(R,G,"CG")$ | Use table commodity structure of government consumption |
| $UseStruct_{2010}(R,G,"NPISH")$ | Use table commodity structure of NPISH consumption |

**Annex 9 FIDELIO estimated parameters**

| Parameter | Description | Value |
|---|---|---|
| $c_1^{aids}(R, QC)$ | Parameter governing household consumption in QIDS products | |
| $c_{QC}^{aids}(R, QC, QC)$ | Parameter governing household consumption in QIDS products | |
| $c_2^{appl}$ | Parameter governing household consumption in appliances | 0.54 |
| $c_3^{appl}$ | Parameter governing household consumption in appliances | 0.68 |
| $c_2^{el}$ | Parameter governing household consumption in electricity | 0.21 |
| $c_3^{el}$ | Parameter governing household consumption in electricity | 0.59 |
| $c_4^{el}$ | Parameter governing household consumption in electricity | 0.13 |
| $c_2^{fuel}$ | Parameter governing household consumption in fuel | 0.38 |
| $c_3^{fuel}$ | Parameter governing household consumption in fuel | 0.69 |
| $c_4^{fuel}$ | Parameter governing household consumption in fuel | -0.47 |
| $c_2^{heat}$ | Parameter governing household consumption in heating | 0.10 |
| $c_3^{heat}$ | Parameter governing household consumption in heating | 0.84 |
| $c_4^{heat}$ | Parameter governing household consumption in heating | 0.46 |
| $c_2^{hou}$ | Parameter governing household consumption in housing | 0.90 |
| $c_3^{hou}$ | Parameter governing household consumption in housing | -0.35 |
| $c_4^{hou}$ | Parameter governing household consumption in housing | -0.18 |
| $c_5^{hou}$ | Parameter governing household consumption in housing | -1.42 |
| $c_6^{hou}$ | Parameter governing household consumption in housing | 0.04 |
| $c_7^{hou}$ | Parameter governing household consumption in housing | 0.12 |
| $c_2^{nond}$ | Parameter governing household consumption in non-durables | 0.23 |
| $c_3^{nond}$ | Parameter governing household consumption in non-durables | -0.14 |
| $c_4^{nond}$ | Parameter governing household consumption in non-durables | -0.82 |
| $c_5^{nond}$ | Parameter governing household consumption in non-durables | 0.01 |
| $c_2^{veh}$ | Parameter governing household consumption in vehicles | 0.43 |
| $c_3^{veh}$ | Parameter governing household consumption in vehicles | 0.02 |
| $c_4^{veh}$ | Parameter governing household consumption in vehicles | 0.91 |
| $c_5^{veh}$ | Parameter governing household consumption in vehicles | -0.36 |
| $c_6^{veh}$ | Parameter governing household consumption in vehicles | -0.81 |
| $c_7^{veh}$ | Parameter governing household consumption in vehicles | 0.02 |
| $c_8^{veh}$ | Parameter governing household consumption in vehicles | 0.02 |
| $c_9^{veh}$ | Parameter governing household consumption in vehicles | 0.86 |

**Annex 10 FIDELIO parameters from literature**

| Parameter | Description | Value |
|---|---|---|
| $\delta^{appl}$ | Depreciation rate of appliances | 0.07 |
| $\delta^{hous}$ | Depreciation rate of houses | 0.015 |
| $\delta^{veh}$ | Depreciation rate of vehicles | 0.08 |
| $\theta$ | Collateral for household durables | 0.37 |
| $\sigma^{K\_L\_E}$ | Substitution elasticity between capital, labour, and energy | 0.95 |
| $\sigma^{KLE\_M}$ | Substitution elasticity between KLE and materials | 0 |
| $\sigma_{Arm}(R, G)$ | Armington elasticitiy | |
| $DeprRate$ | Depreciation rate of capital stock | 0.05 |
| $fprod(R, S, "Capital")$ | Parameter of capital productivity in the second CES nest | 1 |
| $fprod(R, S, "L")$ | Parameter of labour productivity in the second CES nest | 1 |
| $fprod(R, S, "E")$ | Parameter of energy productivity in the second CES nest | 1 |
| $KRemuner$ | Remuneration of capital | 0.03 |

**Annex 11 FIDELIO countries and abbreviations**

| Country | Abbreviation |
|---|---|
| European Countries | |
| Austria | AUT |
| Belgium | BEL |
| Bulgaria | BGR |
| Croatia | HRV |
| Cyprus | CYP |
| Czech Republic | CZE |
| Denmark | DEN |
| Estonia | EST |
| Finland | FIN |
| France | FRA |
| Germany | DEU |
| Greece | GRC |
| Hungary | HUN |
| Ireland | IRL |
| Italy | ITA |
| Latvia | LVA |
| Lithuania | LTU |
| Luxembourg | LUX |
| Malta | MLT |
| Netherlands | NLD |
| Poland | POL |
| Portugal | PRT |
| Romania | ROU |
| Slovakia | SVK |
| Slovenia | SVN |
| Spain | ESP |
| Sweden | SWE |
| United Kingdom | GBR |
| Non-European countries | |
| Brazil | BRA |
| China | CHN |
| India | IND |
| Japan | JPN |
| Russia | RUS |
| Turkey | TUR |
| United States | USA |
| Rest of the world | ZROW |

**Annex 12. Energy commodities (plus losses) in the WIOD satellite accounts**

| | WIOD Code | IEA Code |
|---|---|---|
| COAL | | |
| Hard coal and derivatives | HCOAL | ANTCOAL + BITCOAL + COKCOAL + PATFUEL + SUBCOAL |
| Lignite and derivatives | BCOAL | BKB + CAOLTAR + LIGNITE + PEAT |
| Coke | COKE | GASCOKE + OVENCOKE |
| | CRUDE & FEEDSTOCKS | |
| Crude oil, NGL and feedstocks | CRUDE | CRUDEOIL + NGL + REFFEEDS +ADDITIVE + NONCRUDE |
| PETROLEUM PRODUCTS | | |
| Diesel oil for road transport | DIESEL | GASDIES(1)* |
| Motor gasoline | GASOLINE | MOTORGAS |
| Jet fuel (kerosene and gasoline) | JETFUEL | AVGAS + JETGAS + JETKERO |
| Light Fuel oil | LFO | GASDIES(2)* |
| Heavy fuel oil | HFO | RESFUEL |
| Naphtha | NAPHTA | NAPHTA |
| Other petroleum products | OTHPETRO | BITUMEN + ETHANE + LPG + LUBRIC+ ONONSPEC + OTHKERO + PARWAX+ PETCOKE + REFINGAS + WHITESP |
| GASES | | |
| Natural gas | NATGAS | NATGAS |
| Derived gas | OTHGAS | BLFURGS + COKEOVGS + GASWKSGS+ MANGAS + OXYSTGS |
| RENEWABLES & WASTES | | |
| Industrial and municipal waste | WASTE | INDWASTE + MUNWASTEN +MUNWASTER |
| Biogasoline also including hydrated ethanol | BIOGASOL | BIOGASOL + OBIOLIQ |
| Biodiesel | BIODIESEL | BIODIESEL |
| Biogas | BIOGAS | GBIOMASS |
| Other combustible renewables | OTHRENEW | CHARCOAL + RENEWNS + SBIOMASS |
| ELECTRICITY & HEAT | | |
| Electricity | ELECTR | ELECTR |
| Heat | HEATPROD | HEAT + HEATNS |
| Nuclear | NUCLEAR | NUCLEAR |
| Hydroelectric | HYDRO | HYDRO |
| Geothermal | GEOTHERM | GEOTHERM |
| Solar | SOLAR | SOLARPV + SOLARTH |
| Wind power | WIND | WIND |
| Other sources | OTHSOURC | BOILER + CHEMHEAT + HEATPUMP +OTHER + TIDE |
| LOSSES | | |
| Distribution losses | LOSS | DISTLOSS |

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