MIO-ES: A Macroeconomic Input-Output Model with Integrated Energy System

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"*If you want something you've never had, you must be willing to do something you've never done.*" Thomas Jefferson

Preface

The evaluation and analysis of energy and environmental policy has been a major issue of economic modelling during the last two decades. The first generation of models applied in this area was dominated by CGE models like GEM-E3, developed by Klaus Conrad and others at ZEW (Conrad, Schmidt, 1998). An alternative macroeconomic input-output (IO) model (E3ME) has been developed by Terry Barker and his team at Cambridge Econometrics (Barker, 1999). Worldwide, several CGE models have been constructed, mainly based on the GTAP dataset. Another global (fully interlinked) macroeconomic IO model that has been used for European policy analysis is the GINFORS model developed by the team of Bernd Meyer at GWS (Lutz, et al., 2010). All these models integrate the (final) energy consumption into the production process and into the consumption activities without a detailed and explicit modelling of the energy system and energy transformation processes. Recently, impact analysis of the European climate and energy policy has usually been carried out applying a suite of models. The most recent study on the "Long-Term Strategy" (EU Commission, 2018) has used PRIMES, PRIMES-TREMOVE, models for land use and agriculture (CAPRI, GLOBIOM-G4M, GAINS), as well as macroeconomic CGE und IO models (GEM-E3, E3ME), plus a DSGE-model (QUEST) in parallel. As far as the use of the economic models and the link to the energy system-models is concerned, only part of the results of the energy system-models have been introduced in those models ("super-soft link"). Additionally, the bottom-up model FORECAST (Fleiter, et al., 2018) that describes the whole energy system in detail, has been applied.

This manual describes the first version of the macroeconomic energy IO model MIO-ES that has been built during the year 2019 in a joint effort between CESAR and UBA (Umweltbundesamt). It is a concrete and visible sign of UBA's engagement in economic analysis of the Austrian energy system and its links to the economic system. CESAR started the project by collecting and organizing the data and implementing an example model file. During the first quarter of 2019 several courses about the model structure, the data and the implementation have been given by CESAR's team. People from UBA have contributed by collaborating in the calibration of parameters, supplying databases and deciding about the features of the final version of MIO-ES. A special thank goes to Johanna Vogel for delivering valuable comments on a first draft of this manual.

The philosophy of MIO-ES for energy modelling is the full integration of the energy system into the IO model framework. That comprises full consistency between the IO and the energy balance concept as well as of physical and monetary data and the description of energy transformation processes. The purpose of this full integration is to fully link the bottom-up datasets and models applied in Austrian energy and climate policy analysis to the economic system and therefore integrating all feedbacks between the two systems. That refers, e.g. to the economic impact of decarbonization or the price and income rebound effects of climate policy. The IO framework chosen for that is the hybrid IO model (Miller and Blair, 2009) with measuring the non-energy part in monetary units and the energy part in physical units. Besides using mixed units, another issue for consistent integration of the energy system is a correct representation of energy transformation processes (Kratena and Schleicher, 1999). As Guevara (2017) has shown, the standard hybrid energy IO model is not fully consistent with the energy balance concepts of 'final energy demand' and 'energy transformation (input and output)'. He therefore proposes a two-stage IO model framework that is also the basis of MIO-ES. Though the model is set up in hybrid units, at some stages they need to be converted into each other using the implicit prices following from a simple division. In MIO-ES, these conversions are reduced to a minimum and only serve to derive important variables (GDP) in monetary units. In that way, the general specification of the hybrid model is conserved.

The philosophy of MIO-ES for modelling the economy can be seen as New Keynesian in the sense that in the long-run, the model operates like a Computable General Equilibrium (CGE) model, but in the short run – due to institutional rigidities – can exhibit Keynesian features (see: Kratena et al., 2017). The extent to which Keynesian features (more explicitly multiplier effects of demand shocks) are present, depends on the state of the economy. If the economy is close to full employment equilibrium, demand shocks will mainly lead to increases in wages and prices and only small income and employment effects will be realized. The model is similar to a CGE model, as factor demand as well as final demand (consumption, investment) depend on relative prices. The restrictions from factor markets materialize via liquidity constraints for consumers and wage reactions to the unemployment gap.

This preface is also a wonderful opportunity to thank all the people that have made the building of MIO-ES possible. We want to thank all those persons at UBA who have supported and initiated the work with MIO-ES: Georg Rebernig, Manfred Ritter, Elisabeth Rigler, Sigrid Svehla-Stix, Ilse Schindler and Günther Lichtblau. These people are also continuously pushing the future development of MIO-ES and gave us the opportunity to use the just finished model for policy simulations. The core team at UBA that has already been applying the model consists of Johanna Vogel and Konstantin Geiger, whom we want to thank for all their assistance during the project. The construction of MIO-ES would not have been possible without all the people that gave advice for the modelling structure (in order to incorporate relevant features for policy simulations) and supplied data: Erwin Mayer, Tom Krutzler, Nikolaus Ibesich, Gudrun Stranner, Holger Heinfellner, Thomas Gallauner, Herbert Wiesenberger, Wolfgang Schieder and Bernd Gugele. Besides that, we also want to thank the other participants for their patience in attending the courses on MIO-ES: Sabine Kunesch and Michael Kellner.

Given the Spanish background of CESAR (it has originally been funded in Spain in 2015), it might be added that "mio es" incidentally means "it's mine" in Spanish. While at the beginning of the project that could have been said by the CESAR team only (though just being 'owned' in the imagination of the people from CESAR), at the end of the project and of a very fruitful cooperation, every member of the MIO-ES group at UBA can claim that the model contains their contribution and therefore is his/her. Hopefully, all these 'owners' will use it in the future for analysing the relevant energy and climate policy questions of our times.

1. The framework of the hybrid energy-IO model

The hybrid model measures all energy flows in physical units, whereas all other flows are measured in monetary units. It is set up as a partitioned IO model with two parts: (i) non-energy and (ii) energy. The model for part (i) solves for the vector in hybrid units, comprising final energy demand (physical) and the gross output of non-energy industries (monetary). The model for part (ii) solves for output (primary and transformation) of energy industries (physical). The only link between physical and monetary units works via implicit prices of the output of energy by industries. The main shortcomings of energy-IO models where total or primary energy input is simply attached to the gross output of industries, is that it does not deal consistently with the different concepts of *'final demand'* in IO and energy statistics and therefore does not describe the energy transformation processes in a correct way. This, in turn, in simulations yields misleading results for economic and energy impacts of changes in the energy system. The application of the hybrid model with two model parts and a partition into energy and non-energy flows overcomes this shortcoming. The final demand in the IO tables only comprises the demand of final users (consumption, investment, exports), whereas in energy statistics 'final energy consumption' is the sum of all energy use that is *not* used for transformation. Therefore, 'final energy consumption' also includes energy demand by industries, which in IO statistics is accounted for as intermediate demand. In energy statistics, intermediate energy demand is the use of primary energy for energy transformation (coke ovens, refinery, electricity generation, etc.). This gap in the concepts is overcome in the hybrid model by including 'final energy consumption' in the solution of part (i) and in part (ii) describing the energy transformation processes with energy output as the model solution. Both parts are linked and need to be solved simultaneously.

The framework of both models are SUT (Supply-Use tables) based on the publication of the IO Table 2014 of Statistics Austria. This is complemented by the Energy Balance 2014, the Structural Business Survey 2014, and some other minor data sources for energy and mining (all from Statistics Austria). The supply table contains the production of goods by industries and covers all the non-characteristic production, like e.g. metal products and electricity produced by the steel industry. The use table contains the use (= input) of domestic and imported goods by industries and final users (private consumption, gross fixed capital, formation, exports, changes in stocks, and public consumption). These two tables are available in monetary units for 2014.

1.1. The non-energy part of the hybrid IO model

The first step towards the hybrid model consists of setting all energy flows in both tables equal to zero and replacing them by energy flows in physical units. That results in the following components of part (i) of the IO model framework:

$\mathbf{V}_{NE}$: The **non-energy supply table** (industries * goods) in monetary units. This is derived from the original supply table of the IO table 2014 ($\mathbf{V}$) by setting **energy goods** (columns) equal to zero. The column sum of this matrix gives the vector of output by goods (without energy goods), $\mathbf{q(g)}_{NE}$. The row sum of the matrix is defined as the vector of output by industries (without energy goods production), $\mathbf{q}_{NE}$. For the model solution we need the **total** (**energy plus non-energy**) output vector by goods and by industries in monetary units. The total output vector by goods ($\mathbf{q(g)}$) is the column sum of the original supply table ($\mathbf{V}$), the total output vector by industries from the original supply table ($\mathbf{V}$) is $\mathbf{q}$. Additionally defining the total energy output by industries in monetary units as $\mathbf{q}_{E,v}$ means that total output $\mathbf{q}$ is the sum $\mathbf{q}_{NE}$ + $\mathbf{q}_{E,v}$. This energy output by industries in monetary units ($\mathbf{q}_{E,v}$) is defined by the product of the output by industries $\mathbf{q}_{E}$ (physical units) and **implicit prices** ($\mathbf{p}_{E,v}$) for energy output ($\mathbf{q} = \mathbf{q}_{NE} + \mathbf{p}_{E,v}\, \mathbf{q}_{E}$). These implicit prices are simply derived from the data by dividing $\mathbf{q}_{E,v}$ through $\mathbf{p}_{E,v}$. Energy output by goods in physical units is $\mathbf{q(g)}_{E}$.

$\mathbf{U}^{d}_{NE}$: The **non-energy domestic use table** (goods * industries and goods * final demand components) in monetary units. This is derived from the original domestic use table of the IO table 2014 ($\mathbf{U}^d$) by setting **energy goods** (columns) equal to zero. The row sum of this matrix gives the **non-energy** vector of output by goods, $\mathbf{q(g)}_{NE}$.

$\mathbf{U}^{im}_{NE}$: The **non-energy imports use table** (goods * industries and goods * final demand components) in monetary units. This is derived from the original use table of the IO table 2014 ($\mathbf{U}^{im}$) by setting **energy goods** (columns) equal to zero. The row sum of this matrix gives the **non-energy** vector of imports by goods, $\mathbf{im}_{NE}$.

$\mathbf{f}^d_{NE}$ and $\mathbf{f}^{im}_{NE}$: The **non-energy** vectors of **final demand**, comprising **domestic** (d) and **imported** (im) goods ($\mathbf{f}^{im}_{NE}$ is part of $\mathbf{im}_{NE}$).

In this framework, all identities of the standard IO model based on supply and use tables are fulfilled. That applies to the commodity balance for non-energy goods (supply = use): $\mathbf{q(g)}_{NE}$ + $\mathbf{im}_{NE}$ = $\mathbf{f}_{NE}$ + $\mathbf{x}_{NE}$, where is intermediate demand $\mathbf{x}_{NE}$, i.e. the row sums of $\mathbf{U}^d_{NE}$ and $\mathbf{U}^{im}_{NE}$ without final demand. The same commodity balance holds for all goods (energy and non-energy): $\mathbf{q(g)}$ + $\mathbf{im}$ = $\mathbf{f}$ + $\mathbf{x}$. The GDP identity holds (in current prices) for the base year 2014 (with prices = 1 for all goods): **GDP** = $\mathbf{q} - \mathbf{x} = \mathbf{f} - \mathbf{im}$. For all other years of the simulation period (2015 – 2050), GDP is calculated from the demand side ($\mathbf{f} - \mathbf{im}$) only in order to avoid implausible results for value added deflators from double deflation. Final demand **f** is the sum of the following components: private consumption (**cp**), capital formation (**cf**), stock changes (**st**), exports (**ex**) and government consumption (**cg**): $\mathbf{f} = \mathbf{cp} + \mathbf{cf} + \mathbf{st} + \mathbf{ex} + \mathbf{cg}$. Total imports **im** are given by: $\mathbf{cp}^{im} + \mathbf{cf}^{im} + \mathbf{st}^{im} + \mathbf{ex}^{im} + \mathbf{cg}^{im} + \mathbf{x}^{im}$, where $\mathbf{x}^{im}$ is the imported intermediate demand

The second step towards the hybrid model consists of reconstructing all energy flows that have been set equal to zero in the first place by the corresponding energy flows in physical units. That results in the following components of part (i) of the IO model framework:

$\mathbf{U}_E$: The **energy use table** (energy types * industries) in physical units. The row sum of this matrix (including final demand according to the IO concept) is the vector of the final energy demand (according to the **energy balance concept**) by energy types, $\mathbf{x}_E$. The column sum of this matrix is the physical energy input vector, **e**. The final energy demand $\mathbf{x}_E$ (energy balance concept) comprises intermediate (input-output concept) energy demand by industries $\mathbf{x}_{E,j}$, and final (input-output concept) demand components: private consumption ($\mathbf{c}_E$) and exports ($\mathbf{ex}_E$) plus some constant vectors (non-energy use, transport losses, energy sector use).

The supply and use tables described above are converted into coefficients matrices for setting up the IO model. From the supply table $\mathbf{V}_{NE}$ the non-energy 'market shares matrix' $\mathbf{D}_{NE}$ is derived by dividing the matrix elements through the column sum, $\mathbf{q(g)}_{NE}$. An element $q_{ij}/q(g)_j$ of this matrix $\mathbf{D}_{NE}$ defines the participation of industry *i* in the production of good *j*. This matrix links the non-energy output by industries $\mathbf{q}_{NE}$ to the non-energy output by goods $\mathbf{q(g)}_{NE}$: $\mathbf{q}_{NE} = \mathbf{D}_{NE}\, \mathbf{q(g)}_{NE}$.

From the domestic intermediate use table $\mathbf{U}^d_{NE}$ the non-energy domestic 'technical coefficients matrix' $\mathbf{B}^d_{NE}$ is derived by dividing through the vector of total output by industries, **q**. From the use table of energy in physical units $\mathbf{U}_E$ we derive the energy 'technical coefficients matrix' $\mathbf{B}_E$ by dividing each element through the vector of total output by industries, **q**. The elements x_{ij}/q_j of $\mathbf{B}^d_{NE}$ and $\mathbf{B}_E$ define the input *i* in the production of one unit of industry *j*, therefore they determine domestic intermediate demand $\mathbf{x}^d_{NE}$ and $\mathbf{x}_{E,j}$ as a function of output by industries **q**.

Additionally, a non-energy imported 'technical coefficients matrix' $\mathbf{B}^{im}_{NE}$ exists, that is derived from the import use matrix, $\mathbf{U}^{im}_{NE}$.

As a next step we define 'use structure' matrices that describe the structure of inputs of intermediates and energy within the row vectors of inputs **en** and **m**. These 'use structure' matrices $\mathbf{S}^{d}_{M}$, $\mathbf{S}^{m}_{M}$ and $\mathbf{S}_{E}$ are derived by dividing each element of $\mathbf{U}_{E}$ by **en** and each element of $\mathbf{U}^{d}_{NE}$ and $\mathbf{U}^{m}_{NE}$ by **m**. The column sum of ($\mathbf{S}^{d}_{M} + \mathbf{S}^{m}_{M}$) and of $\mathbf{S}_{E}$ therefore is equal to 1. The row vectors **en** and **m** are in constant prices and are calculated by multiplying nominal factor shares with the inverse of the real factor prices:

$$\mathbf{en} = \frac{p_E en}{pq}\frac{p}{p_E}q \qquad \mathbf{m} = \frac{p_M m}{pq}\frac{p}{p_M}q \tag{1}$$

For energy, this input vector must be further converted into the dimension of physical energy inputs, **e**. This is done by applying fixed conversion factors. Defining **en/q** and **m/q** as diagonalized matrices *diag***EN** and *diag***M**, we can define the matrices of technical coefficients $\mathbf{B}_{E}$ and $\mathbf{B}^{d}_{NE}$ as the product of *diag***EN** and *diag***M** with the corresponding use structure matrix:

$$\mathbf{B}_{\mathrm{E}} = diag\mathbf{EN}\,\mathbf{S}_{\mathrm{E}} \qquad \mathbf{B}^{\mathrm{d}}_{\mathrm{NE}} = diag\mathbf{M}\,\mathbf{S}^{\mathrm{d}}_{\mathrm{M}} \tag{2}$$

Therefore, in this framework, the matrices of technical coefficients ($\mathbf{B}_{E}$, $\mathbf{B}^{d}_{NE}$, and $\mathbf{B}^{im}_{NE}$) are not defined directly, but in a nested structure. First, the row vectors of inputs **en** and **m** are defined and then, in the second nest, these aggregate input coefficients are split up into technical coefficients applying fixed structures according to the IO (Leontief) technology.

1.2. The energy part of the hybrid IO model

For part (ii) of the IO model framework the following components are constructed from energy balance data:

$\mathbf{V}_{E}$: The **energy supply table** (industries * energy types) in physical units, covering primary energy as well as transformation output. The column sum of this matrix gives the vector of energy output by energy goods in physical units is $\mathbf{q(g)}_{E}$. The row sum equals the vector of energy output by industries, $\mathbf{q}_{E}$ in physical units as well.

$\mathbf{U}_{EE}$: Use table (energy types/primary energy * industries) in physical units. The row sum (including final energy demand, $\mathbf{x}_{E}$, stock changes and subtracting energy imports) of this matrix gives the vector of energy output by energy types, $\mathbf{q(g)}_{E}$.

Final demand: This table consists of the final energy demand, $\mathbf{x}_{E}$ plus stock changes $\Delta\mathbf{s}_{E}$, minus energy imports $\mathbf{im}_{E}$ (according to the **energy balance concept**).

In order to derive these matrices, the energy balance (Statistics Austria) had to be reclassified to match the industry classification of part (i) of the IO model. Final energy demand ($\mathbf{x}_{E}$) in the energy balance is disaggregated by 21 sectors that can be matched with the 79 NACE industries of MIO-ES. Information for splitting up the energy demand for each energy type across industries are in general taken from the structure of energy demand (monetary units) in the use table of IO statistics. For renewables, the lowest level of aggregation of energy types has been applied for splitting up the input across the 79 NACE industries. That made it possible to directly assign some energy inputs (e.g. black liquor) to certain industries in the 79 NACE classification. In a similar way, energy output ($\mathbf{q}_E$) and energy input in transformation had to be disaggregated into the 79 NACE industry classification. First, energy output ($\mathbf{q}_E$ and $\mathbf{q(g)}_E$) had to be disaggregated from the six processes in the energy balance to the 79 NACE industries, using structural information from the supply table of IO statistics. This was especially relevant for electricity production, for which in the energy balance only information at the level of two processes (energy & heat generation, autoproducers) is available. In a second step, energy input in transformation had to be disaggregated into the 79 NACE industries, corresponding to the disaggregation of energy output.

For part (ii) of the IO model, the commodity balance (IO concept) needs to hold as well, at the level of energy types: $\mathbf{x}_E + \mathbf{x}_{EE} = \mathbf{q(g)}_E + \Delta\mathbf{s}_E - \mathbf{im}_E$. The final demand by energy type plus the transformation input $\mathbf{x}_{EE}$ equals the output by energy type $\mathbf{q(g)}_E$ plus stock changes $\Delta\mathbf{s}_E$, *minus* energy imports $\mathbf{im}_E$. As far as energy output is concerned, two types of output can be differentiated according to the energy balance concept: primary energy output (e.g. crude oil or natural gas) and transformation output (e.g. diesel or electricity) depending on the energy type. The part (ii) of the IO model covers energy both on the output as well as on the input side. In energy production, primary energy types are dealt with as a primary input from nature, and in energy transformation as an input of the corresponding energy type. For energy analysis it is not the commodity balance that is used for deriving the main indicators. Instead, the emphasis is on **gross energy consumption** as an indicator for the domestically used primary energy. This gross consumption is given as: total use ($\mathbf{x}_E + \mathbf{x}_{EE}$) *minus* transformation output by energy type $\mathbf{q(g)}_E$ and *minus* exports $\mathbf{ex}_E$.

The general philosophy of the hybrid model is to have the two parts with monetary units and physical units separated but both based on their respective statistical sources, without adjusting the data in order to match any restrictions. For some variables, though, a conversion from physical units into monetary units and vice versa is necessary. This conversion is in MIO-ES reduced to the absolute minimum of variables and implemented via **implicit prices**. The implicit price (vector) of private energy consumption $\mathbf{p}_{E,C}$ links the consumption of energy goods in physical units, $\mathbf{cp}_E$ with energy consumption by energy goods $\mathbf{cp}_{E,v}$ and the implicit price (scalar) of energy stock changes and exports links energy stock changes and exports (total) in physical units to the aggregates in monetary values. As stock changes and exports in physical units are dealt with as constant, stock changes and exports in monetary values are constant as well. Besides that, the implicit price $\mathbf{p}_{E,v}$ of energy output (as described above) is used as well.

In analogy to the derivation of the non-energy coefficient matrices, the energy 'market shares matrix' $\mathbf{D}_E$ can be derived from supply matrix $\mathbf{V}_E$ via dividing through the column sum, which is the vector of energy output by energy types, $\mathbf{q(g)}_E$. The element $q_{ik}/q(g)_k$ of $\mathbf{D}_E$ represents the participation of industry *i* in the production of energy type *k*, and the matrix $\mathbf{D}_E$ links the energy output by industries $\mathbf{q}_E$ to the energy output by goods $\mathbf{q(g)}_E$: $\mathbf{q}_E = \mathbf{D}_E\, \mathbf{q(g)}_E$.

From the energy transformation use matrix $\mathbf{U}_{EE}$ we derive the matrix of 'technical coefficients' of energy transformation/production $\mathbf{B}_{EE}$ (dividing through the column sum. i.e. the vector of energy output by industries, $\mathbf{q}_E$). The element $e_{kj}/q_{E,j}$ of $\mathbf{B}_{EE}$ represents the input of energy type *k* in the total production of energy by industry *j*. The part (ii) of the IO model is solved for the energy output by industries, $\mathbf{q}_E$, which then is transformed into monetary units $\mathbf{q}_{E,v}$ and added to non-energy output $\mathbf{q}_{NE}$ by industries, in order to derive total $\mathbf{q}$. This total output $\mathbf{q}$ is reinserted into part (i) of the IO model to solve for the total output vector by goods **q**(**g**) and final energy consumption $\mathbf{x}_E$. This is the link from part (ii) to part (i) of the model. The link from part (i) to part (ii) works via re-inserting final energy consumption ($\mathbf{x}_E$) into the model for energy transformation (see section 3).

In general, for the energy industries, the technical coefficient matrices are directly defined and not in a nested structure as in the case of the non-energy industries. An exemption is the electricity generation, where both *real* factor shares and technical coefficients are determined in a bottom-up model that is linked to the IO model.

2. The IO price model

The nested structure of the factor demand with aggregate energy (**en**) and intermediates (**m**) on the one hand and the goods composition within these aggregate factors (matrices $\mathbf{S}^d_M$, $\mathbf{S}^m_M$ and $\mathbf{S}_E$) on the other hand allows for linking any microeconomic production or cost function model (Cobb-Douglas, CES, etc.) to the IO structure, captured within $\mathbf{S}^d_M$, $\mathbf{S}^m_M$ and $\mathbf{S}_E$. The framework of the production structure of MIO-ES therefore is similar to CGE models (like GEM-E3), which usually also apply nested structures and fixed (Leontief) technolgy at the lowest level of the goods structure of intermediate inputs (see, e.g., Conrad and Schmidt, 1998). Energy is often treated in a different way in CGE models in the sense that the second nest (in our case matrix $\mathbf{S}_E$) is not fixed, but modelled as flexible due to price dependent inter-fuel substitution. This is also implemented in MIO-ES. In the case of constant returns to scale, factor demand can be directly modelled at the level of unit costs and therefore with a direct link to output prices. The output price is then determined from the unit cost definition or the unit cost function and not by the solution (Leontief inverse) of the IO price model. The essence of the IO price model is integrating the feedback of output prices on input prices (of intermediates) and this feature is actually kept in the price model of MIO-ES and extended towards the price of capital inputs. Output prices from the unit cost function determine – together with exogenous import prices - the price of intermediates $\mathbf{p}_M$ as well as the price of capital $\mathbf{p}_K$. These prices, in turn, exert a feedback in the factor demand functions and in the output price equation.

2.1. Prices and factor demand for non-energy industries

The IO price model includes a model of factor demand for *K* (capital), *L* (labour), *E* (energy), *M* (intermediates) as factors of production and an output price (*p*) equation for the non-energy industries. The feedbacks of the IO price model are integrated via loops for the price of capital, p_K, and the price of intermediates, p_M. The factor demand functions *K*, *L*, *E*, *M* are derived from the Translog unit cost function at industry level with constant returns to scale and perfect factor and goods markets. That yields the *nominal* factor shares according to Shephard's lemma:

$$\frac{p_K k}{pq} = \alpha_K + \gamma_{KK} log\left(\frac{p_K}{p_M}\right) + \gamma_{KL} log\left(\frac{p_L}{p_M}\right) + \gamma_{KE} log\left(\frac{p_E}{p_M}\right) + \rho_{tK} t$$

$$\frac{p_L l}{pq} = \alpha_L + \gamma_{KL} log\left(\frac{p_K}{p_M}\right) + \gamma_{LL} log\left(\frac{p_L}{p_M}\right) + \gamma_{LE} log\left(\frac{p_E}{p_M}\right) + \rho_{tL} t$$

$$\frac{p_E en}{pq} = \alpha_E + \gamma_{KE} log\left(\frac{p_K}{p_M}\right) + \gamma_{LE} log\left(\frac{p_L}{p_M}\right) + \gamma_{EE} log\left(\frac{p_E}{p_M}\right) + \rho_{tE} t$$

$$\frac{p_M m}{pq} = 1 - \frac{p_K k}{pq} - \frac{p_L l}{pq} - \frac{p_E en}{pq} \quad (3)$$

Equation (1) defines how these *nominal* factor shares are converted into real factor shares (in the case of energy further into a physical/monetary real share) and thereby have a feedback on the technology matrices $\mathbf{B}_E$, $\mathbf{B}^d_{NE}$, and $\mathbf{B}^{im}_{NE}$ (equation (2)). The parameters γ in equation (3) measure the influence of factor prices on factor demand, and the parameters ρ measure the „factor-bias" of technical change via the deterministic trend *t*. For the parameters γ symmetry and homogeneity restrictions apply. In the Translog model, the definition of price elasticities of factor demand, i.e. the logarithmic change in input quantity x_i with respect to a logarithmic change of the own input price p_i or another input price p_j is a function of the price parameters γ and the nominal factor shares v_i, v_j:

$$\varepsilon_{ii} = \frac{\partial log x_i}{\partial log p_i} = \frac{v_i^2 - v_i + \gamma_{ii}}{v_i} \qquad \varepsilon_{ij} = \frac{\partial log x_i}{\partial log p_j} = \frac{v_i v_j + \gamma_{ij}}{v_i} \quad (4)$$

Table 1 contains selected own- and cross-price elasticities for selected industries derived from panel data estimations (pooling across 27 EU countries) based on the WIOD database (www.wiod.org) that have been carried out in the context of the second version of the FIDELIO model (Kratena, et al., 2017). The sample average (1995 – 2014) elasticities for Austria are the main result of these estimation results that we want to stick to for factor substitution in MIO-ES. As they are functions of the parameters *and* the nominal factor shares in a certain point of time, we need to calculate the parameters γ for the Austrian factor shares in 2014. This is simply done by inverting the elasticity formulae (equation (4)). Once the parameters γ have been calculated, the functions in equation (3) can be calibrated for 2014 for each industry. It must be noted here, that the WIOD classification is an aggregate of the 79 NACE industries of MIO-ES. Therefore, the same elasticity had to be used for calibration in the case of NACE industries falling into one WIOD category. Furthermore, for the non-energy intensive manufacturing industries (mainly coinciding with the non-ETS sectors) the Translog model has been calibrated only for *K* (capital), *L* (labour), and *M* (intermediates) factors. For energy, a log-linear function for the nominal factor share has been specified by applying the own price elasticity for energy from Table 1.

Table 1: Price elasticities (1995-2014) of factor demand, Translog model

	Labour	Energy	Capital/Labour	Capital/Energy
Food, Beverages and Tobacco	-0.4939	-0.4939	0.0990	0.0381
Textiles and Textile Products	-0.4420	-0.7412	0.2054	0.0352
Wood and Products of Wood and Cork	-0.2891	-0.7428	0.5193	0.1446
Pulp, Paper, Paper , Printing and Publishing	-0.5756	-0.5780	0.2834	0.0634
Coke, Refined Petroleum and Nuclear Fuel	**-0.1340**	**-0.3027**	**0.2161**	**1.6516**
Chemicals and Chemical Products	**-0.7526**	**0.0000**	**0.0956**	**0.1613**
Rubber and Plastics	-0.5687	-0.3669	0.2164	0.0313
Other Non-Metallic Mineral	**-0.6532**	**-0.6727**	**0.1952**	**0.1711**
Basic Metals and Fabricated Metal	**-0.4182**	**-0.9855**	**0.2419**	**0.1330**
Electrical and Optical Equipment	-0.9885	-0.0136	0.1794	0.0295
Machinery, Nec	-0.7805	-0.0932	0.2502	0.0222
Transport Equipment	-0.7811	-0.9585	0.0380	0.0297
Manufacturing, Nec; Recycling	-0.5899	-0.8336	0.1415	0.0166
Electricity, Gas and Water Supply	**-0.7255**	**-0.7145**	**0.1481**	**0.4214**
Wholesale Trade	-0.6756	-0.5378	0.2066	0.0107
Retail Trade	-0.4063	-0.7210	0.4052	0.0372
Inland Transport	-0.4697	-0.0878	0.2454	0.0233
Water Transport	-0.6957	-0.0507	0.1875	0.0766
Air Transport	-0.5891	-0.6351	0.1982	-0.1944
Other Supporting Transport Activities	-0.4164	-0.6002	0.1034	0.0345
Post and Telecommunications	-0.5413	-1.0145	0.1753	0.0159
Hotels and Restaurants	-0.2937	-0.7952	0.2425	0.0655
Average	**-0.5582**	**-0.5427**	**0.2088**	**0.1372**

Source: own calculations from FIDELIO (Kratena, et al., 2017) background material

The elasticity values in Table 1 reveal that on average there is no significant difference between the own-price elasticity of labour and of energy. The average value of about -0.5 is compatible with a linear homogenous factor demand function in output. It can also be observed that the own-price elasticity of energy is not systematically higher in energy-intensive industries than in others. The cross-price elasticity between capital and labour is on average higher than the cross-price elasticity between capital and energy. A remarkable result is that, except air transport, capital and energy are substitutes in all (selected) industries. Former studies, based for example on EUKLEMS (Kratena, 2007) found that capital and energy were complements in several industries in EU countries. Note that Table 1 reports price and not substitution elasticity values. For comparing the results with the existing literature on substitution elasticities, the price elasticities of Table 1 need to be converted into substitution elasticities first. Applying the formula for 'Allen's elasticity of substitution (AES)', this sis simply carried out by dividing the cross-price elasticity by the nominal factor share of the factor *j*. Given that the average labour share is about 0.2, the average substitution elasticity between capital and labour is about unity. This is a relatively higher value than the one found in former studies working with CES specifications, where the values were significantly below unity. The literature on increasing inequality between labour and capital income stresses the importance of an increase of the capital-labour substitution elasticity over time. This is in line with the values we use in MIO-ES from 2014 on. As the nominal factor share of energy is lower (on average) than the one for labour, the capital-energy substitution elasticity is also around unity on average and considerably higher for energy-intensive industries. Especially the coke/refinery industry and the electricity sector show a high capital-energy substitution elasticity. It must be noted, though, that the elasticity values for these two industries are not used in MIO-ES to describe factor demand. The energy industries are partially linked to bottom-up models where the factor demand is determined (see section 2.2).

The main price equation is the equation for output prices by industry p and is given by the aggregator of the Divisia price index which is consistent with the Translog cost function aggregator.

$$p = \exp\left(\Sigma_i\, v_i \log p_i\right) \quad ; \qquad \mathbf{p(g,NE)} = \mathbf{p}\ \mathbf{D}_{NE} \qquad (5)$$

The market shares matrix $\mathbf{D}_{NE}$ converts the (row) vector **p** into the **goods price** vector, **p(g,NE)**. The prices of energy goods are converted from the vector **p** of energy industries (see section 2.2) by applying $\mathbf{D}_{E}$. As in CGE models, the IO price model of MIO-ES represents a full matrix system of composite prices of goods flows for each industry and final demand component. The composite price of a goods flow for industry j in the use matrix (intermediate and final) is the weighted sum of the domestic goods price $p(g)_{i,j}$ and the exogenous import price, $p(im)_{i,j}$. At this stage of the model, factor demand and output prices are determined when the input prices for K, L, E and M are given. The next step consists of partially endogenizing the input prices via the feedbacks of the IO price system and leaving other prices as exogenous (for the moment).

The energy prices of k energy types, $\mathbf{p}_{E,k}$, and the import prices of non-energy goods, p^{im}_{NE}, are both determined by world market prices and are the key exogenous prices in MIO-ES (the ‚numeraire' in CGE language). The price for the energy bundle in each industry, i.e. the input price vector of energy, $\mathbf{p}_{E}$, is given as the product of the prices of k energy types, $\mathbf{p}_{E.k}$ and the energy input matrix $\mathbf{S}_{E}$. In the Non-ETS (European Emission Trading System) industries of MIO-ES, log linear functions for inter-fuel substitution are in place. That refers to oil products (where a distinction is made between fuels for transport and others) and gas. The substitution effects depend on the relative prices in relation to the electricity price, so that the own-price elasticity and the cross-price elasticity for electricity are defined in one step:

$$\log(s_{oil}) = \alpha_{0,oil} + \gamma_{1,oil} \log(p_{oil}/p_{el})$$

$$\log(s_{gas}) = \alpha_{0,gas} + \gamma_{1,gas} \log(p_{gas}/p_{el})$$

$$s_{el} = 1 - \Sigma_k\, s_k \qquad (6)$$

The s are the coefficients within the column of matrix $\mathbf{S}_{E}$ by industry. A price shock for a certain k energy type therefore has an impact on the price vector of the energy bundle $\mathbf{p}_{E}$ that already takes into account quantity reactions due to the price change. The energy input matrix $\mathbf{S}_{E}$ is therefore not fixed.

The price of labour l is endogenous in MIO-ES and will be explained in section 4. The feedbacks of the IO price system are active for the price of capital k and the price of intermediates m. The price of capital formation is specified according to a user cost of capital - concept for each industry j with $p_{CF,j}\ (r + \delta_j)$, where r is a rate of return (constant at 4%) and δ_j is an industry-specific depreciation rate of capital. The price vector of investment for industries $\mathbf{p}_{CF,j}$ is made up of two components: (i) the price of each investment good (investment being industry *j*) is the weighted sum of $p(g)_{i,CF}$ and $p(im)_{i,CF}$, and (ii) the resulting vector of investment goods prices, $\mathbf{p}_{CF,}$ is converted into $\mathbf{p}_{CF,j}$ by applying the investment coefficient matrix $\mathbf{S}_{CF}$. This matrix can be split up into a part of imported investment goods $\mathbf{S}^{im}{}_{CF}$ and a part of domestic investment goods, $\mathbf{S}^{d}{}_{CF}$. The column sum over both matrices equals unity and shows the shares of goods entering in the investment of each industry. The import part reflects the import content of the capital formation vector in the use table. As $p(g)_{i,CF}$ depends on $\mathbf{p(g)}$ and therefore - in turn - on the output price vector $\mathbf{p}$, the price of capital is directly endogenous via the price system:

$$\mathbf{p}_{K} = [\mathbf{p(g,NE)}\mathbf{S}^{d}{}_{CF} + \mathbf{p}(\mathrm{im})\,\mathbf{S}^{im}{}_{CF}\,](r + \delta) \tag{7}$$

The price vector of intermediates $\mathbf{p}_{M}$ by industries is directly given by the product of goods prices (domestic and imported) and the use structure matrices:

$$\mathbf{p}_{M} = \mathbf{p(g,NE)}\,\mathbf{S}^{d}{}_{M} + \mathbf{p}(\mathrm{im})\,\mathbf{S}^{im}{}_{M} \tag{8}$$

Therefore, the IO price model directly integrates the two loops: (i) from $\mathbf{p(g,NE)}$ to $\mathbf{p}_{CF,j}$ and to $\mathbf{p}_{K}$ as well as back to $\mathbf{p}$ and $\mathbf{p(g,NE)}$, and (ii) from $\mathbf{p(g;NE)}$ to $\mathbf{p}_{M}$ and back to $\mathbf{p}$ and $\mathbf{p(g,NE)}$. In the full model MIO-ES, additionally the price of labour $\mathbf{p}_{L}$ is endogenous, and depends – *inter alia* – on the price index of private consumption, p_{CP}. The latter can also be expressed as a function of goods prices, import shares of consumption goods (matrix $\mathbf{IM}_{CP}$) and the (column) vector of budget shares in private consumption, $\mathbf{w}_{CP}$. The feedback from consumer prices to the price of labour $\mathbf{p}_{L}$ represents an additional loop. The solution of the price model can be written in the following form:

$$log\mathbf{p} = log\mathbf{p}(log\mathbf{p}_{K}, log\mathbf{p}_{L}, log\mathbf{p}_{E}, log\mathbf{p}_{M})$$

$$\mathbf{p(g)} = \mathbf{p_q}\,\mathbf{D}_{NE} + \mathbf{p_q}\,\mathbf{D}_{E}$$

$$\mathbf{p}_{K} = [\mathbf{p(g,NE)}\mathbf{S}^{d}{}_{CF} + \mathbf{p}(\mathrm{im})\,\mathbf{S}^{im}{}_{CF}\,](r + \delta)$$

$$\mathbf{p}_{M} = \mathbf{p(g)}\,\mathbf{S}^{d}{}_{M} + \mathbf{p(im)}\,\mathbf{S}^{im}{}_{M}$$

$$p_{CP} = [\mathbf{p(g)}(\mathbf{I} - \mathbf{IM}_{CP}) + \mathbf{p}(\mathrm{im})\,\mathbf{IM}_{CP}]\,\mathbf{w}_{CP} \tag{9}$$

2.2. Prices for energy industries and links to bottom-up models

The energy industries in MIO-ES are the following NACE sectors: 191 Coke, 192 Refined petroleum products, 3511 Electricity generation, 3512-3514 Other electricity, 352 Gas distribution, 353 Steam and air conditioning supply. These industries are formally integrated into the IO price model as well as into the Translog model but dealt with in a different way.

The coke sector does not exist in monetary units, as this process is integrated into the basic metal industry and coke output and input are internal deliveries and do not represent an economic transaction (though a physical input). For the refinery sector we assume fixed input coefficients of the *K*, *L*, *E* and *M* factors. Note that in both cases the input of *E* (final energy demand) is zero, as these industries are part of the energy transformation processes. Fixed input coefficients of the K, L, E and M factors are also assumed for other electricity, gas distribution, as well as for steam and air conditioning.

The energy inputs of electricity generation are determined by linking bottom-up information at the technology level to aggregate data from IO and energy statistics. The output of the electricity sector q_{el} comprises electricity and heat and can be measured in monetary as well as in physical inputs, both linked with each other by an implicit price. From the energy balance we know the generation of electricity and heat by each technology τ (e.g. CHP gas, power plant coal, power plant wind) and therefore the share of each technology in producing total output, w_{τ}. Each technology is defined by the input of one type of energy k. The input coefficient of k per unit of output produced is the inverse of the efficiency of each technology, $\eta_{k,\tau}$. The input coefficient for each energy type k in the electricity sector column of matrix $\mathbf{B}_{EE}$ is therefore given by the equation:

$$b_k = \sum_{\tau} \frac{w_{\tau}}{\eta_{k,\tau}} \tag{10}$$

The total energy output per unit of output en/q is then given as the column sum of equation (10), converting the physical/monetary coefficient e/q into the real monetary coefficient. For simulations, the technology shares w_{τ} are taken from a partial model of the energy system (TIMES) and inserted into equation (10). The efficiency parameters $\eta_{k,\tau}$ might as well be changed according to exogenous technology information.

The inputs of labour and intermediates might as well be a function of the technology shares w_{τ}, but this is not considered in the current version of MIO-ES. The input of capital is linked to the bottom-up information. For this purpose, the capital costs of different electricity generation technologies are taken from the literature (Fraunhofer ISE, 2018) and multiplied with the technology shares w_{τ} to arrive at an estimate of the aggregate capital costs of the electricity sector. The equation is then calibrated by adding a constant term β_K, so that it yields exactly the capital cost (operating surplus per output) term of the use table.

$$\frac{k}{q} = \beta_K + \sum_{\tau} w_{\tau} \frac{k_{\tau}}{q_{\tau}} \tag{11}$$

Fixed real factor shares for labour (f_L) and intermediates (f_M) plus the real shares en/q and k/q are then used to calculate the output price of the electricity sector for given input prices:

$$p = \left(\frac{en}{q} p_E + \frac{k}{q} p_K + f_L p_L + f_M p_M \right) \tag{12}$$

For the electricity sector, equation (12) substitutes the general price equation $log\mathbf{p} = log\mathbf{p}(log\mathbf{p}_K, log\mathbf{p}_L, log\mathbf{p}_E, log\mathbf{p}_M)$ and the output price is converted into a goods price via the term for energy industries/goods in the goods price equation ($\mathbf{p_q}\,\mathbf{D}_E$).

3. The IO quantity model

As has been already noted, the solution of the price model has a repercussion on the quantity model, as the technical coefficient matrices change when the input prices of production factors change. Besides that, the quantity model solves, once the vector of final demand is given. As has already been said, final demand comprises two parts, namely energy consumption by households in physical units, stock changes of energy goods and exports of energy goods, i.e. $\mathbf{f}_{\mathrm{E}}$ as well as domestic monetary final demand $\mathbf{f}^{\mathrm{d}}_{\mathrm{NE}}$.

Part (i) of the model is then written as:

$$\begin{bmatrix} \mathbf{x}_{\mathrm{E}} \\ \mathbf{q}(\mathbf{g})_{\mathrm{NE}} \end{bmatrix} = \begin{bmatrix} \mathbf{B}_{\mathrm{E}} \\ \mathbf{B}^{\mathrm{d}}_{\mathrm{NE}} \end{bmatrix} \mathbf{q} + \begin{bmatrix} \mathbf{f}_{\mathrm{E}} \\ \mathbf{f}^{\mathrm{d}}_{\mathrm{NE}} \end{bmatrix}$$

$$\mathbf{q}_{\mathrm{NE}} = \mathbf{D}_{\mathrm{NE}} \mathbf{q}(\mathbf{g})_{\mathrm{NE}}$$

$$\mathbf{q} = \mathbf{q}_{\mathrm{NE}} + \mathbf{p}_{\mathrm{E,q}} \mathbf{q}_{\mathrm{E}}$$

It determines the final energy demand (in the definition of energy balances) in physical units $\mathbf{x}_{\mathrm{E}}$ and the non-energy output by goods and industries, $\mathbf{q(g)}_{\mathrm{NE}}$ and $\mathbf{q}_{\mathrm{NE}}$.

Part (ii) of the model describes the energy production (from natural sources, e.g crude oil) and the energy transformation (e.g. refinery products):

$$\mathbf{q}(\mathbf{g})_{\mathrm{E}} = \mathbf{B}_{\mathrm{EE}} \mathbf{q}_{\mathrm{E}} + \mathbf{x}_{\mathrm{E}} - \mathbf{im}_{\mathrm{E}} + \Delta \mathbf{s}_{\mathrm{E}}$$

$$\mathbf{q}_{\mathrm{E}} = \mathbf{D}_{\mathrm{E}} \mathbf{q}(\mathbf{g})_{\mathrm{E}}$$

This part determines energy output by goods and industries in physical units, when final energy demand in physical units $\mathbf{x}_{\mathrm{E}}$, imports $\mathbf{im}_{\mathrm{E}}$ and stock changes $\Delta\mathbf{s}_{\mathrm{E}}$ are given.

Both parts need to be solved simultaneously (in one loop), as the first part determines $\mathbf{x}_{\mathrm{E}}$ when energy and non-energy output are given and the second part determines energy output $\mathbf{q}_{\mathrm{E}}$, when $\mathbf{x}_{\mathrm{E}}$ is given. The link is the implicit price vector $\mathbf{p}_{\mathrm{E,v}}$.

4. Final demand

In MIO-ES the two components of final demand, that are explicitly modelled and described hereafter, are private consumption and gross fixed capital formation. Trade flows are partly exogenous (exports) and partly endogenous (imports). For exports that are inserted exogenously for every model simulation, the user can - after a first model run - take the output price effects from the model results and by combining them with assumed price elasticities for exports by good, estimate a new export vector. In a second model run, this new export vector can be inserted additionally for solving the model. Note that this only seems appropriate in the case of simulations of unilateral Austrian energy and climate policies. In the case of a European policy scenario, impacts on price competitiveness are negligible and might be excluded. Imports are determined by the detailed import shares for each user (industry) and the corresponding level of demand of the user. That means that prices are absent for explaining the splitting up of goods demand into domestic and imported goods. That can easily be overcome in an extended future version of MIO-ES by introducing gravity equations for trade (imports). Again, as in the case of exports, this is most relevant in a scenario of a unilateral Austrian policy. Public consumption is in general exogenous in MIO-ES. It can be – after a first model run – adjusted in order to follow a certain path of public deficit of public deficit/GDP.

4.1. Private consumption

The module for private consumption comprises three nests and ten groups of household income (deciles). The first nest determines aggregate consumption of each household decile, depending on disposable income and the *marginal propensity of consumption* of the decile. The second nest determines energy relevant consumption expenditure by decile, which is linked to data used in bottom-up models for private transport and private buildings (and their respective energy consumption). This second nest comprises two durable spending categories and four non-durables. The third nest determines spending on eight non-durable non-energy categories and is specified as an Almost Ideal Demand System (AIDS). The six energy relevant consumption categories and the eight non-durable non-energy categories are further distributed across the 82 CPA categories, applying fixed sub-shares. In a last step the energy consumption which is determined in physical units by k energy types partly in the bottom-up models and partly in MIO-ES is converted into the energy goods in MIO-ES (coal, coke, refined petroleum products, electricity, gas, and steam/air conditioning) in monetary units. All that is done at the level of the ten income groups of households (deciles). Summing up over the deciles gives the final private consumption vector in purchaser prices. This vector is finally transformed into a consumption vector at basic prices by rearranging margins and subtracting net taxes. The vectors for each decile are used to calculate the budget shares for all 82 CPA categories of each decile ($\mathbf{w}_{CP}$) and the derivation of an income group-specific consumer price p_{CP} according to equation (9). Note that data at basic prices and purchaser prices are in MIO-ES not only used for expenditure, but also for goods prices of consumption. For each good and for each of the aggregated categories (14) in the consumption basket, both, a basic price and a purchaser price are defined. For those categories, for which consumers' demand reacts to prices, it is the purchaser price that determines the level of demand. That allows for simulating tax policy at the level of goods.

4.1.1. Income and wealth distribution and aggregate consumption

Total private consumption is endogenized in MIO-ES in the same way as in a Social Accounting Matrix (SAM)-model (see: Miller and Blair, 2009). The difference is that the link between income generated in value added and the flows between the household sector and the other institutional sectors (public sector, external sector) are not integrated into an extended SUT matrix system, but are added to the equation system that is then solved in loops (see: Kratena, 2017). The use table covers the following components of value added: wages (including social security contributions of employers) wL, operating surplus plus net taxes, P. Part h_{CP} (in 2014 about 22%) of profits P is redistributed to households and enters disposable income. Other income categories and flows between households and other institutional sectors are not generated in production but depend on other variables. The main data sources for income distribution are the results from EUSILC, published by Statistics Austria and by WIFO. From different sources (Austrian National Bank, Household Finance and Consumption Survey, HFCS) additionally data on assets (A) and on consumer debt (D) have been collected at the level of deciles of disposable income. The flows between the household and the public sector are: transfers (Tr) as well as social security contributions with t_L as the social security rate and income taxes on all income categories with t_Y as the income tax rate.

The definition for disposable income YD is given by:

$$YD_t = w_tL_t + h_{CP}P_t + r_tA_{t-1} - i_tD_{t-1} + Tr_t - t_L(w_tL_t) - t_Y(w_tL_t + h_{CP}P_t + i_tA_{t-1}) \quad (13)$$

Positive property income is given as an interest on assets in (t-1) and negative property income is an interest on consumer debt in (t-1). The data collection has been carried out separately for stocks and flows by deciles, so that the interest rates r and i are effective rates, derived from the data. The resulting values for these effective interest rates are also used as a plausibility check for the dataset. As Table 2 shows, the implicit or effective interest rates for assets and consumer debt resulting from combining the estimation of stocks and flows across deciles from the existing data sources are within a plausible range. Whereas the average propensity of consumption shows a continuous decrease over income groups, the distribution of the effective tax rates is slightly discontinuous, though it reveals the expected result of increasing income tax rates with income and decreasing social security rates. As information for a 'perfect' SAM with links between income by industry and income by household decile is missing, we distribute total wages and operating surplus across the deciles according to the shares in the base year. The same is done for the distribution of social transfers.

Table 2: Variables and parameters: distribution of disposable income

	average prop.cons.	tax rate income	tax rate soc.security	interest rate assets	interest rate debt	Wages shares (%)	Oper.surplus shares (%)	Soc. transfers shares (%)
dec1	1.080	-1.6%	29.3%	2.16%	1.08%	0.7%	1.7%	5.8%
dec 2	1.038	23.5%	38.7%	2.72%	1.08%	1.5%	3.7%	9.1%
dec3	0.999	11.7%	42.0%	2.49%	1.08%	2.6%	4.0%	11.2%
dec4	0.977	15.5%	38.3%	2.45%	1.08%	4.1%	5.0%	12.0%
dec5	0.958	17.1%	38.1%	2.05%	1.08%	6.0%	5.0%	12.4%
dec6	0.949	15.2%	36.6%	2.12%	1.08%	8.5%	8.1%	10.7%
dec7	0.930	15.6%	36.3%	1.81%	1.08%	11.3%	8.3%	10.2%
dec8	0.921	17.3%	36.2%	1.69%	1.08%	14.7%	8.4%	9.9%
dec9	0.906	17.9%	35.6%	1.66%	1.08%	19.3%	14.1%	9.3%
dec10	0.873	21.1%	28.8%	3.02%	1.08%	31.3%	41.7%	9.4%
TOTAL	0.933	18.0%	34.1%	2.22%		100.0%	100.0%	100.0%

Source: Statistics Austria, WIFO, Austrian National Bank, HFCS, own calculations

Total non-energy consumption by decile is partly a simple Keynesian log-linear consumption function, (depending on YD/p_{CP}), partly a PIH (permanent income hypothesis) model. The 20% at the bottom of income distribution are hand-to-mouth consumers, the 30% at the top are PIH consumers. The Keynesian consumption function for income group h is:

$$\log CP_h = c_{0,h} + mpc_h \log(YD_h/p_{CP,h}) \quad (14)$$

The marginal propensity of consumption (mpc) by decile is set with:

decile 1,2: 1
decile 3: 0.8
decile 4: 0.7
decile 5: 0.6
decile 6: 0.5

decile 7: 0.4
decile 8,9,10: 0

The average *mpc* following from this distribution is 0.5. Keynesian income multipliers work out in MIO-ES, when demand shocks increase *YD* more than p_{CP}. This, in turn, depends on the wage feedback of the demand shock and therefore on the state of the economy relative to the full employment equilibrium (see section 4 below).

Due to the different consumption structures, each decile faces its own consumer price, $p_{CP,h}$. As is laid down in equation (9), prices of private consumption are determined at the level of goods by $\mathbf{p(g)}\ (\mathbf{I} - \mathbf{IM}_{CP})$ and $\mathbf{p(im)}\ \mathbf{IM}_{CP}$. This equation determines prices as basic prices (= 1 in the base year) which are in a first step converted into basic prices, net of margins and of taxes minus subsidies (≠ 1 in the base year). Dividing these net basic prices by $(1 - t_{tt} - t_{tax})$ with t_{tt} as margin rates and t_{tax} as net indirect tax rates, gives purchaser prices (= 1 in the base year). The purchaser prices are then aggregated to prices of the *m* (14) categories, and $p_{CP,m}$ is calculated for each decile *h* of the consumption model by using sub-shares $w_{CP,h,m}$ for the *m* categories, with $p_{CP,m} = \Sigma_h\ w_{CP,h,m}\ p_{CP,h,m}$. The energy price and the shares of energy are added exogenously. The aggregate consumption price can then be calculated over all goods either as in equation (9) or over the *m* categories plus energy:

$$p_{CP} = \Sigma_m (p_{CP,m}\ w_{CP,m}) + p_{CP,E} w_{CP,E} \qquad (15)$$

4.1.2. Energy relevant consumption and links to bottom-up models

The energy relevant consumption is in MIO-ES linked to the bottom-up results of the partial energy models (NEMO, EEG/TU Vienna). This energy relevant consumption covers two durable categories: (i) rents, and (ii) vehicles, as well as four non-durable categories: (i) maintenance of dwellings, (ii) maintenance of vehicles, (iii) air transport, and (iv) other (public) transport. One important link to the bottom-up models works via the relationship between physical and monetary flows by defining implicit prices. This is done for the area of dwelling (mill m^2), where an implicit price of 2,500 €/m^2 has been estimated and for the vehicle stock, where the resulting implicit price is about 21,300 €/vehicle. Another link via an implicit price is implemented for the flow of public transport. That results in a value of 6.6 €-cent per km of public transport services.

The following energy relevant physical data are taken from the bottom-up models:

Dwelling area (mill m^2)
Vehicle stock, gasoline
Vehicle stock, diesel
Vehicle stock, electric
Total person-km
Person-km, bus
Person-km, rail
Person-km, other public transport

For vehicles, the stock changes are converted into expenditure flows CP_{veh} via inverting the capital accumulation equation:

$$K_{t,veh} = (1 - d_{veh})\, K_{t-1,veh} + CP_{veh} \quad (16)$$

In the case of housing, the expenditure (actual and imputed rents) is defined via a user cost of capital-concept (as is the case in National Accounts), where the housing stock K_{hous} has been derived from multiplying the implicit price (€/m^2) with the dwelling area (mill m^2):

$$CP_{t,hous} = p_{t,hous}(r_t + d_{hous})\, K_{t-1,hous} \quad (17)$$

Energy consumption in physical units for heating, electricity and car travel is linked with a specific consumption measure (that is subject to technical progress) to the stock data. For heating, this is simply a measure of specific consumption (in kWh/m^2) that changes with the substitution of old by new houses and by a higher renovation rate. Electricity consumption is in the same way linked to the (monetary) appliance stock plus the electricity consumed in driving electric cars. The energy demand (physical) for gasoline, diesel and electricity for driving is simultaneously determined by two factors of influence from the bottom-up models, that can be changed for policy simulations. One is the number of person-km in the three modes of public transport (bus, rail, other) that determines the person-km driven in cars as a residual. Given the vehicle stock distribution, one gets the total person-km in cars and the person-km in each mode. Policies that increase the person-km in public transport, therefore reduce person-km in cars proportionally for all drives. The vehicle stock distribution together with the specific consumption (TJ/person-km) then finally determines the energy demand for driving by energy types k.

Table 3: Variables: energy relevant consumption

	Rents (share)	Dwellings, user costs (%)	Dwellings, renov. rate (%)	Person-km (share)	Vehicles (share)
dec1	3.50%	3.61%	0.35%	3.63%	3.73%
dec 2	7.08%	3.61%	0.15%	7.39%	2.10%
dec3	8.21%	3.61%	0.33%	6.83%	3.63%
dec4	9.41%	3.61%	0.12%	8.04%	7.87%
dec5	9.66%	3.61%	0.23%	9.14%	6.83%
dec6	9.56%	3.61%	0.27%	9.19%	10.59%
dec7	10.46%	3.61%	0.27%	7.89%	10.94%
dec8	10.79%	3.61%	0.41%	9.41%	12.50%
dec9	12.02%	3.61%	0.46%	13.09%	14.15%
dec10	19.31%	3.61%	0.46%	25.38%	27.66%
TOTAL	100.00%		0.31%	100.00%	100.00%

Source: Statistics Austria, Austrian National Bank, HFCS, Verkehrsdaten Österreich, own calculations

The distribution of energy relevant consumption across deciles is estimated based on the available statistical sources. There are several implicit variables (relationships) that follow from the combination of stock and flow data at the decile level, which again serve as a plausibility check (Table 3). Applying a uniform user cost rate that follows from data for all households across deciles together with the distribution of the housing stock, gives the expenditure for rents (actual plus imputed). Relating the expenditure for maintenance of dwellings to the housing stock K_{hous} yields an average renovation rate of 0.3%, which is slightly lower than the 'official' renovation rate for buildings in the dataset of the bottom-up models. That needs to be considered in policy simulations when the energy efficiency of the building stock is to be increased by a higher renovation rate. The distribution of person-km and the vehicle stock across income deciles has been estimated as well and is shown in Table 3.

4.1.3. Non-energy consumption

Expenditures for the eight non-energy consumption categories are modelled in an AIDS (Almost Ideal Demand System) approach, where the nominal budget shares w_i are functions of prices and total expenditure. Note that the eight categories *i* (food, beverages, tobacco, household durables, clothing, household appliances, other manufacturing, other housing, health, other services) are different aggregates of the 82 CPA goods for each decile, so that their prices p_j are different for each decile:

$$w_i = \alpha_i + \sum_j \gamma_{ij} log p_j + \beta_i log\left(\frac{CP_{NE}}{PC_{NE}}\right) \tag{18}$$

In (18), C_{NE} is the nominal expenditure for non-energy consumption. The Translog price index for PC_{NE} that is derived from the AIDS expenditure function has been approached by the Stone price index (log $PC_{NE} = \Sigma_i w_i \log p_i$). This is in analogy with applying the Divisia price index for output prices in the Translog model (equation (5)). The derivation of compensated price elasticities yields:

$$\varepsilon_{ij} = \frac{\partial log cp_i}{\partial log p_j} = \frac{\gamma_{ij} - \beta_i w_j}{w_i} - \delta_{ij} + \varepsilon_i w_j \tag{19}$$

In (19) δ_{ij} is the Kronecker delta with $\delta_{ij} = 0$ when $i = j$ and zero otherwise. The elasticities for calibrating the AIDS model have been taken from panel data and cross section estimation results in the course of constructing the FIDELIO model (Kratena, et al., 2017). We do not assume, in general, different elasticities by deciles, so that in calibrating the model, due to the different budget shares for each decile, we get different parameters by decile. Table 4 shows the budget shares across deciles for the eight categories.

Table 4: Budget shares of non-energy consumption

	Food, beverages, tobacco	Household durables	Clothing	Household appliances	Other manufacturing	Other housing	Health	Other services
dec1	23.45%	7.63%	7.97%	4.96%	10.30%	0.14%	4.18%	41.38%
dec 2	30.71%	6.53%	7.08%	4.96%	9.62%	0.19%	4.21%	36.71%
dec3	27.23%	7.62%	7.43%	4.59%	11.04%	0.17%	4.47%	37.46%
dec4	26.73%	6.09%	7.69%	4.72%	9.72%	0.16%	4.30%	40.60%
dec5	25.46%	6.80%	6.88%	4.71%	9.95%	0.16%	4.92%	41.10%
dec6	23.11%	8.13%	6.67%	5.23%	10.14%	0.14%	5.06%	41.52%
dec7	24.44%	7.52%	8.41%	4.95%	9.84%	0.14%	4.01%	40.69%
dec8	24.31%	7.87%	8.06%	4.92%	10.62%	0.14%	4.19%	39.89%
dec9	23.32%	8.28%	7.52%	4.81%	10.61%	0.13%	4.23%	41.09%
dec10	20.56%	8.02%	8.72%	4.98%	10.16%	0.11%	4.24%	43.22%
TOTAL	23.89%	7.64%	7.84%	4.90%	10.22%	0.14%	4.36%	41.00%

Source: Statistics Austria, own calculations

The own and cross price elasticities show a considerable variety across goods. The distribution of positive and negative signs of cross price-elasticity values is almost even, indicating a balanced relationship between substitutability and complementarity of different goods.

Table 5: Price and expenditure elasticities of non-energy consumption

	Food, beverages	Household durables	Clothing	Household appliances	Other housing	Health	Other services	**expenditure elasticity**
Food, beverages, tobbacco	-0.14	-0.05	0.05	-0.05	-0.10	0.40	0.40	0.48
Household durables	-1.20	-1.06	-0.05	0.50	0.20	-0.15	1.00	1.48
Clothing	-0.40	-0.05	-0.64	-0.05	-0.05	0.10	0.13	1.44
Household appliances	-1.00	0.50	-0.05	-0.60	-0.20	-0.15	1.00	1.10
Other housing	0.70	-0.50	0.10	-0.50	-0.50	0.10	0.60	1.00
Health	1.50	-0.15	0.25	-0.15	0.20	-0.83	-0.30	1.43
Other services	0.90	0.40	-0.30	0.40	-0.30	-0.50	-0.68	1.07

Source: own calculations from FIDELIO (Kratena, et al., 2017) background material

The variety of expenditure elasticities is based on the cross-section estimation results for the FIDELIO model, where household budget surveys of six EU countries have been used. The elasticity values shown in Table 5 represent the characteristic values for Austria.

4.2. Gross fixed capital formation

Investment demand has a double classification like the use matrix of intermediate inputs. Statistics Austria provides an investment matrix in the published IO statistics for 2014. This matrix links capital formation by industry (*j*) cf_j with the vector of capital formation by goods (**cf**) from the use table. The matrix therefore shows the investment goods structure of the capital formation for each industry. The row sum of the investment matrix is the SUT vector of capital formation (**cf**) and the column vector is capital formation by industry ($\mathbf{cf}_j$). In a perfect capital market, investment by industry could directly be derived from the optimal capital coefficient *k*/*q* for each industry. Assuming sluggish adjustment of investment to the optimal capital stock leads to a flexible function between capital income (operating surplus) and investment.

The vector of $\mathbf{cf}_j$ (investment by industry) depends on the industry vector of real operating surplus, $\mathbf{P}/\mathbf{p}_K$. For calibrating these functions in MIO-ES, parameters are taken from the long-run elasticity of $\mathbf{cf}_j$ w.r.t. $\mathbf{P}/\mathbf{p}_K$ in estimations for EU 28 of an Autoregressive Distributed Lag (ARDL)-model:

$$\log(\mathbf{cf_{j,t}}) = \mathbf{A}_0 + \mathbf{A}_1 \log(\mathbf{cf_{j,t\text{-}1}}) + \mathbf{A}_2 \log(\mathbf{P}/\mathbf{p}_{K,t}) + \mathbf{A}_3 \log(\mathbf{P}/\mathbf{p}_{K,t\text{-}1}) \tag{20}$$

where the long-run elasticity by industry is defined as the parameters of the coefficient matrices **A** as follows: $(a_2 + a_3)/(1 - a_1)$. The magnitude of the term $(a_2 + a_3)/(1 - a_1)$ $\mathbf{P}/\mathbf{p}_{K\ t}$ is close to the absolute value of depreciation plus a fixed growth term. That describes the development of sectoral investment in the long-run, and in turn means that MIO-ES does not capture business cycles in investment behaviour in scenarios. Table 5 reveals that on average the long-run elasticity of investment to capital income is about 0.5 with a considerable heterogeneity across industries. The part of investment that is not explained by this long-run elasticity is exogenous in MIO-ES and driven by other investment motives.

Investment demand by good, i.e. the SUT vector of capital formation (**cf**), is finally derived by multiplying the vector of investment by industry ($\mathbf{cf}_j$) with the investment coefficient matrix

S_{CF} (see section 2.1.). The vector of domestic investment goods is given by accounting for imports with the investment good import shares: $\mathbf{cf}^d = (1 - im_{CF})\, \mathbf{cf}$.

5. Labour market

The price of labour has been treated as exogenous in the Translog model of factor demand (section 2.1. above). Therefore, until this point of the model description prices had only a one-way impact on quantities via demand and there was no feedback from quantity to prices via the supply side. In most CGE models, this feedback is present for both factor markets (labour and capital) and for the goods market in the export supply function (Constant Elasticity of Transformation, CET). The trade parameters on the export supply (CET) and import demand (CES, Armington) side together with the restriction for the current account balance (foreign savings) balance the goods market in the standard CGE model. In MIO-ES, no explicit restriction for the current account is in place and on the supply side of goods markets no feedback from prices to quantities is working. With constant returns to scale, demand determines the level of production. The macroeconomic restriction that can be enforced in MIO-ES is a target for the public deficit, so that additional expenditure needs to be balanced by a reduction either in social transfers or in public consumption. Feedbacks from quantity to prices are present in MIO-ES for the factor markets. The price of K is partly endogenous (as far as the investment goods price is concerned) and depends on output prices. When output prices react to demand shocks, that exerts a direct feedback on p_K, therefore. No effect from higher capital demand on the interest rate is assumed, as the financial market is not modelled in MIO-ES but treated as exogenous.

For the price of L, a mechanism is specified in MIO-ES in terms of a wage setting function that incorporates the impact of labour market tightness on the price of labour. The wage setting function for each industry j defines wages (per full time equivalent of employees) as a function of the aggregate consumer price p_{CP}, aggregate productivity Q/L, and the relationship between the actual unemployment rate (ur) and the NAWRU (ur_{eq}):

$$\log(w_j) = a_0 + a_1 \log(p_{CP}) + a_2 \log(Q/L) + a_3 \log(ur/ur_{eq}) \qquad (21)$$

The expected parameter values are $a_1 = 1$, $0 > a_2 < 1$, and $a_3 < 0$, respectively. The NAWRU is determined by applying a Hodrick-Prescott filter to the time series of the Austrian unemployment rate (ur). As in the NAWRU-concept ur can fall below ur_{eq}, the function produces continuously accelerating wage inflation in this range. This is equivalent to the vertical range of a Philipp's curve, which would have been the alternative specification for the wage functions. In equation (21), the price p_{CP} is the aggregate consumption price derived from equation (15). That makes the price of L directly endogenous via the price system. The variables Q/L and ur are derived from the solutions of the price and the quantity model and therefore the price of L is also indirectly endogenous. This indirect mechanism represents the general equilibrium feedback from quantities to prices.

The value for ur_{eq} found in the time series is about 5%. The parameter for the unemployment term (ur/ur_{eq}) has been chosen in the range of the literature and is equal to -0.15 for all industries. In the base year of MIO-ES the actual unemployment rate is very close to the equilibrium rate, so that a maximum of wage feedback is in place for a positive shock on labour demand. A demand shock (public consumption or investment) of 1,000 mill. € generates about 4,000 to 5,000 persons of employment in this state of the economy. The model has also been calibrated with the same parameters but with an actual unemployment rate of 10%. In that case the same demand shock generates more than 10,000 persons of employment. This number is close to what the simple static IO model gives. Table 6 shows that the productivity parameter is on average less than 0.5 with a large variance across industries, This is due to the fact that sectoral trade unions choose a mix between the aggregate productivity and the sector productivity as the measure for their wage claims and minimum wages are often increased more than the average (the share of minimum wage earners varies considerably across industries). The pass through of consumer prices on wages is about unity, as theory suggests.

Table 6: Parameters of the investment and the wage equation (consumer price, productivity, unemployment rate gap)

	investment long-run parameter	consumer price parameter	productivity parameter	unemployment parameter
Food, Beverages and Tobacco	0.35	1.20	0.50	0.15
Textiles and Textile Products	0.59	1.00	0.60	0.15
Wood and Products of Wood	0.49	1.42	0.20	0.15
Pulp, Paper Products	0.45	0.81	0.27	0.15
Chemicals and Chemical Products	0.43	1.00	0.60	0.15
Rubber and Plastics	0.62	1.00	0.60	0.15
Other Non-Metallic Mineral	0.58	1.45	0.60	0.15
Iron & Steel	0.44	1.20	0.42	0.15
Fabricated Metal Products	0.54	1.04	0.13	0.15
Machinery	0.46	1.04	0.13	0.15
Transport Equipment	0.44	0.76	0.45	0.15
Electricity generation	0.63	0.81	0.60	0.15
Wholesale Trade	0.69	1.54	0.28	0.15
Retail Trade	0.35	0.62	0.60	0.15
Land Transport	0.13	0.76	0.25	0.15
Air Transport	0.30	0.51	0.14	0.15
Postal and Courier Activities	0.94	1.04	0.75	0.15
Hotels and Restaurants	0.50	0.40	0.79	0.15
Scientific Research	0.63	1.92	0.29	0.15
Other prof./technical activities	1.00	1.92	0.29	0.15
Other personal services	0.40	1.00	0.60	0.15
Average	**0.52**	**1.07**	**0.43**	**0.15**

Source: own calculations from FIDELIO (Kratena, et al., 2017) background material

6. Public sector

The framework for the public sector comprises the following revenue categories: income taxes, social security contributions, taxes net subsidies on private consumption goods, taxes net subsidies on other demand components, taxes on products (in value added), subsidies on products (in value added), and other revenues. Income taxes and social security contributions accruing to the public sector are the same terms as those in equation (13), where they are subtracted from gross household income. Taxes net subsidies on private consumption goods are attached to the nominal values of consumption at basic prices by a net tax rate. The other net tax revenues that represent a very small share of total taxes net subsidies, are simply linked to the aggregate value of the other final demand components. Taxes on products and subsidies on products are linked to the nominal value of output by industry. Other revenues are exogenous.

Expenditure categories cover: monetary social transfers, public consumption, public investment (four industries), social transfers in kind, subsidies, and other expenditure. In principal, all these categories are exogenous. The user can, in a sequence of simulations, determine an endogenous path for one or for all different expenditure categories that meets a certain target value of the public deficit.

7. Implementing and programming MIO-ES

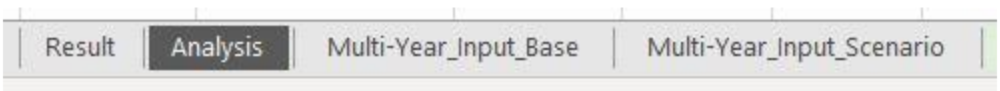
The model is covered by one Excel model file containing macros in Visual Basic for the execution of the model program and with the following sheets:

- User sheets
- Model sheets
- Input data sheets.

The **user sheets** are meant to be the workplace for the user interacting with the program. The **model sheets** integrate all the calculations that are necessary to solve the model. The **base data sheets** contain pure statistical input data of the base year 2014. Both, the model sheets and the base data sheets are of an informative nature only and should not at all be accessed and/or changed by the user. But they can be used to trace the economic interrelationships, intermediate results and the underlying statistical data.

The **model sheets** include the different loops that work within the quantity and the price model as well as in between these two models. The sheet **"Loop_price"** contains the price loop elements for the price vector of investment by industry **p(inv)** and the price vector of intermediates by industry **p(M)** and is exclusively used in the "loop type2" model. The extended model "Loop_price_feedback" additionally incorporates a price-quantity feedback loop on the price of labour **p(L)** which can be found in the sheet **"Loop_price_feedback".** The quantity loops for both models balancing Q(n) and Q(n,E) are implemented via the sheet **"Loop_type2".** Here the user will also find the counterpart of the price-quantity feedback loop. Additional sheets named "**Matrix_B → 2", "Prices → 2 feedback"** and **"imports_type2"** enhance and complete the modelling part.

The relevant **user sheets** are:



The multi-year input sheets **"Multi-Year_Input_Base"** and **"Multi-Year_Input_Scenario"** are the starting point for performing any analysis. They define the dynamic nature of the model over the years. The basic idea behind the split is to allow the comparison of specific scenarios against a predefined base scenario, in short called "base". The correct preparation of these sheets is a prerequisite for further analysis and is supported by a separate process which provides a "copy-paste" possibility to generate the multi-year input.

The “**Analysis**” sheet represents the user interface. Here the user can find the categorized exogenous data sets that has been chosen to be relevant to the analysis. There are two different data classes. Cells highlighted in yellow represent data that is directly linked to the multi-year input sheets. These data will be adapted automatically on a year to year basis defined by the multi-year input sheets and MUST not be changed manually. On the other side, data in cells highlighted in grey are constant over time and can be manually changed if needed.

The model comes in two different variations, “loop type2 model” and “loop type2 model feedback”. Both models include price and quantity modelling. The model with the highest degree of complexity “loop type2 model feedback” additionally incorporates a quantity-price feedback loop and is the default case of the full MIO-ES model.

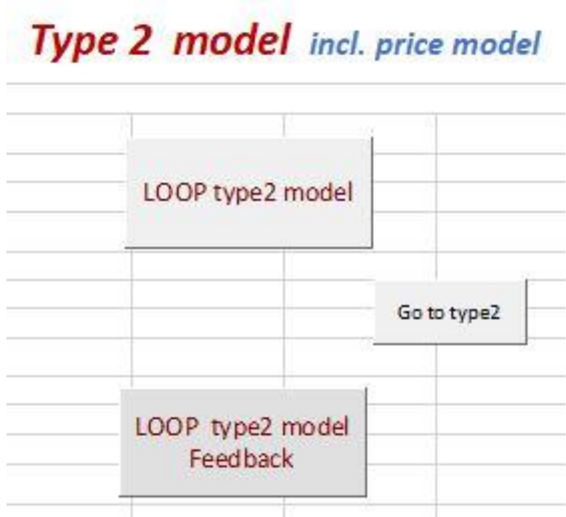
The user’s panel in the **“Analysis”** sheet allows to choose between generating a base or a specific scenario result. By entering “y” or “yes” (BASE yes/no) a base prediction will be calculated and presented in the **“Result”** sheet under “BASE”. By entering “n” or “no” a specific scenario will be calculated and presented in the **“Result”** sheet under SCENARIO. All analyses will start in 2014 (base year) and can be extended until 2050 by defining the final year “End” to be considered.

BASE yes/no	*Start*	*Current*	*End*
y	**2014**	**2014**	**2050**

As the underlying solving algorithm is based on loops, a termination criterion must be defined which determines the accuracy of the outcome. The balance is adequately reached when the difference of the sum of all “quantities” **Q** and the difference of the sum of all “prices” **p** is less than a predefined threshold. The default thresholds are 1E-01 for **Q** and 1E-04 for **p**. In most cases this should be more than adequate, but it can be configured in the user’s panel.

Accuracy	
sum Q	*sum p*
1.00E-01	1.00E-04

The analysis itself is executed by clicking the corresponding button in the **“Analysis”** sheet.



Results can then be found in the **“Result”** sheet that will automatically pop up when starting the analysis. For a complete study the user will find there the base results, the specific scenario results and a comprehensive listing of the differences, if any. For a quick plausibility check, the degree of accuracy of the outcome regarding **Q** and the year being calculated is read out. Moreover, the elapsed time for the entire calculation is presented.

Check Q	Year	Time
✔ 9.41E-04	2014	00:00:10

The **“Result”** sheet of the current version of the MIO-ES model file covers the following endogenous variables:

Gross output (const. prices) by industries
Employment (full time equ.) by industries
Final energy demand by energy types
Real disposable income by decile
Consumption, non-energy consumption by decile
GDP by components, unemployment rate
Public sector revenues by components
Public sector expenditures by components
Net lending, public debt
CO_2 emissions by industries plus households
CO_2 emissions by KSG sectors
CO_2 tax revenues by industries plus households
Final energy by industries and household income deciles
Consumption by expenditure categories
Factor input shares
Price of industries, price of labor by industries, price of consumption by deciles
Value added (const. prices)

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