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The Basic WIOD CGE Model: A Computable General Equilibrium Model Based on the World Input-Output Database

Simon Koesler* and Frank Pothen†

November 15, 2013

Abstract

This report presents the Basic WIOD CGE model. The model represents the first implementation of the World Input-Output Database (WIOD) into the CGE framework and is tailored to provide a maximum fit with WIOD data. The model is specifically designed such that it can serve as the basis for research in fields like environmental, climate and trade policy. It incorporates key features of WIOD such as bilateral and bisectoral trade flows, satellite accounts for energy consumption, greenhouse gas as well as other emissions to air on a sectoral level. As all WIOD data is available in the form of a consistent time series ranging from 1995 to 2009, the model can be calibrated to any year within this time period. The model relies on substitution elasticities which are consistently estimated from the same dataset the model itself is calibrated to. Moreover, the data preparation facilities and model are designed deliberately as flexible as possible in order to allow researchers to use them as a basis for various applications. This enables researchers to secure the numerous advantages of the WIOD dataset when using CGE models for future research.

Keywords:	Computable General Equilibrium Models (CGE), Input-Output, World Input Output Database (WIOD)
JEL-Classification:	C67, C68, E01

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1 Introduction

In modern applied economic research, computable general equilibrium (CGE) models have proven to be one of the key instruments to evaluate alternative policy measures (see e.g. Böhringer et al., 2003; Devarajan and Robinson, 2002; Sue Wing, 2004). At large, numerical models allow for a thorough analysis of economic problems where analytical solutions are either not available or do not provide adequate information due to their simplifying approach. Quantitative simulations facilitate the analysis of intricate economic interactions and the assessment of consequences of structural policy changes. The main advantage of the general equilibrium approach lies thereby in its micro-consistent representation of price-dependent market interactions. The simultaneous explanation of the origin and spending of the agents' income makes it possible to address both economy-wide efficiency as well as distributional impacts of policy interference.

CGE models are frequently used by a big variety of national as well as international organizations for economic policy analysis at the sector- as well as the economy-wide level and have become a standard tool for the quantitative analysis of policy interference in many domains. Examples of their application can be found in many fields ranging from labour economics (e.g. Conrad et al., 2008), climate policy (e.g. Löschel and Otto, 2009; Böhringer et al., 2009), sustainability impact assessment (e.g. Böhringer and Löschel, 2006) and fiscal reform as well as development planning (e.g. Perry et al., 2001; Gunning and Keyzer, 1995).

A large share of CGE models is calibrated on data prepared within the Global Trade Analysis Project (GTAP).[1] Today, the World Input-Output Database (WIOD), developed in a project of the same name, can serve as an alternative basis to parameterize CGE models.[2] The objective underlying WIOD is to construct and apply a dataset capable of accounting for the dynamic socio-economic and environmental interrelatedness of countries and industries (c.f. Timmer et al., 2012; Dietzenbacher et al., 2013). The core of the WIOD database is a set of harmonized supply and use tables (SUT) alongside data on international trade in commodities and services. These two sets of data are integrated into sets of intercountry input-output (IO) tables. Taken together with extensive satellite accounts containing environmental and socio-economic indicators, these industry-level data provide the necessary input to several types of models that can be used to evaluate policies aiming for a suitable balance between growth, environmental degradation and inequality across the world. In this spirit, one of the main tasks of WIOD is to develop models using the new database for applied economic research, inter alia a computable general equilibrium model capable of implementing the WIOD data. In this report we present a basic model implementing some of those features in a straightforward CGE framework.

Making the WIOD data available for the use in policy analysis by means of CGE

[1] Global Trade Analysis Project, http://www.gtap.agecon.purdue.edu

[2] World Input-Output Database, http://www.wiod.org

models allows capturing a range of unique features of the WIOD dataset and brings several ameliorations to the CGE approach:

- Mutually consistent and harmonized SUT and IO tables:
  WIOD tables are harmonized in terms of product- and industry- classifications and in their definitions (such as price concepts). WIOD allows using a single source of harmonized data and avoids combining a large variety of data sources.

- Inter-country Input-output tables:
  WIOD provides bilateral and bisectoral trade flows for all industries and nations covered by the data. It captures international trade in more detail than other datasets and makes it possible to thoroughly investigate changes in trade patterns in a general equilibrium setting.

- Time-series:
  The WIOD database provides consistent time-series of annual IO tables. Time series of variables are required to study and account for developments over time, such as the calibration of time-varying parameters in CGE models.

- Prices and quantities:
  The WIOD-database provides tables at current and constant prices. Constant price tables allow for a distinction between price and quantity developments, which opens up new avenues of research such as transmission of inflationary trends through imports.

- Satellite accounts:
  The WIOD-database provides satellite accounts including data on employment and wages by skills, various types of investment in tangible and intangible assets and environmental indicators in consistent sectoral classification. This allows to implement sub-modules which make it possible to study for example environmental aspects of economic activity in great detail.

- Services:
  By developing a services trade database and by providing maximum detail in service industries, WIOD captures a wide range of sectors that are not taken into account in other databases. An application of WIOD therefore extends the possible range of applications for economic models.

The report is structured as follows. Section 2 of this report describes the individual data sources the Basic WIOD CGE model builds on and presents how the WIOD data is prepared to make it available for the usage in the CGE framework. Subsequently, Section 3 provides a full description of the Basic WIOD CGE model.

2 Preparing the World Input-Output Database for the Model

2.1 Data Sources

CGE models primarily require data describing the flows of income and expenditures in an economy at a certain point in time and elasticities of substitution governing the sensitivity of consumption and production towards (price) shocks. Depending on the desired field of application, the standard CGE data can then be supplemented with information regarding other aspects of economic activity. For example with satellite accounts giving detailed information on labour compensation or environmental issues.

The Basic WIOD CGE model itself draws only on data generated within the framework of the WIOD project (c.f. Timmer et al., 2012; Dietzenbacher et al., 2013). Specifically it uses data describing the overall structure of the economy, energy uses data, data linking economic activity to emissions and substitution elasticities. Figure 1 gives an overview of the data used in the Basic WIOD CGE model and how it is prepared prior to the implementation into the model.

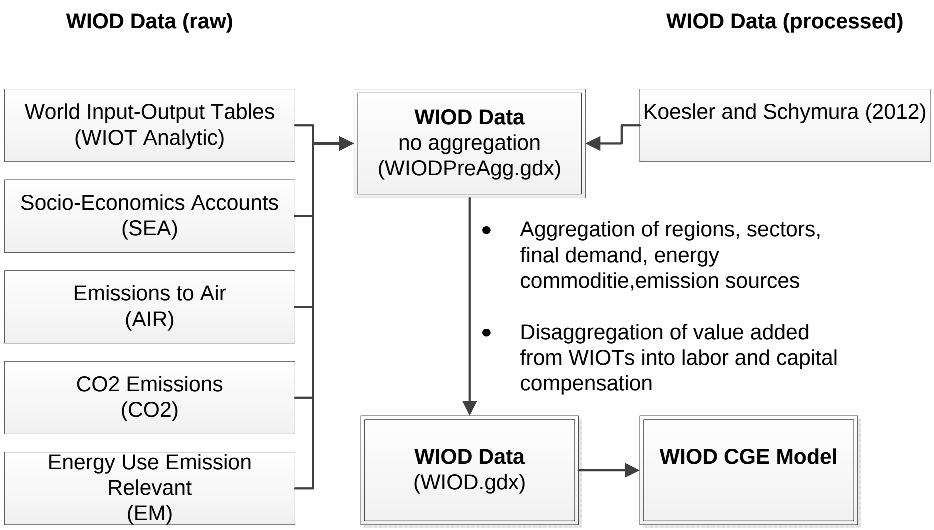

Figure 1: Data Structure

2.1.1 Economic and Trade Data

The basis of any CGE model is the economic structure of an economy in a predefined benchmark year given by an Input-Output (IO) table. An IO table includes information on the production and consumption of every industry and agent specified in the economy and illustrates the relationships between producers and consumers in monetary terms.

To replicate the core economic structure and the trade activities of the economies under investigation, the Basic WIOD CGE model builds on WIOD's World Input-Output Tables (WIOT Analytics). The WIOT Analytics table is a joined set of regional IO covering the whole world. This dataset is available for the years from 1995 to 2009, features data from 40 developed and developing countries as well as a rest of the world region (ROW) and is disaggregated to 35 industries.

For every region, industry and agent covered by WIOD, the current WIOT Analytics features information regarding its intermediate use, final consumption as well as related taxes (net of subsidies), international transport margins, and value added. Furthermore, they contain information on direct purchases on the domestic territory by non-residents, and direct purchases abroad by residents.[3] Figure 2 illustrates the basic structure of the WIOT Analytics.

Unfortunately, WIOT Analytics contain no separate information regarding the compensation for labour and capital services and feature only information on value added. In order to overcome this shortcoming we supplement the WIOT data with information from the WIOD Socio-Economics Accounts (SEA). On a country specific basis, each of these files contains detailed information regarding labour and capital inputs of all industries. From the SEAs we retrieve data on the labour $LAB\_YL_{(r,i,t)}$ and capital $CAP\_YL_{(r,i,t)}$ compensation for each WIOD industry. Subsequently $LAB\_YL_{(r,i,t)}$ and $CAP\_YL_{(r,i,t)}$ are used to disaggregate the value added data from the WIOTs $VA_{(r,i,t)}$ into labour and capital compensation.[4]

[3]For more detailed information regarding WIOTs the interested reader is kindly referred to Timmer et al. (2012)

[4]For some regions WIOD Output and Labour Files contain no information regarding $LAB\_YL_{(r,i,t)}$ and $CAP\_YL_{(r,i,t)}$. Consequently we cannot compute the labour share needed to divide $VA_{(r,i,t)}$. In this case we assume a labour share of $\frac{70}{100}$.

		Region A Intermediate Use Industry	Region B Intermediate Use Industry	Region A Finale Use	Region B Finale Use	Total Output
Region A	Industry	Intermediate use of domestic production	Intermediate use of production from country A in country B	Final use of domestic prodction	Final use of production from country A in country B	Total output of country A
Region B	Industry	Intermediate use of production from country B in country A	Intermediate use of domestic production	Final use of production from country B in country A	Final use of domestic prodction	Total output of country B
Total intermediate consumption						
taxes less subsidies on products						
Cif/ fob adjustments on exports						
Direct purchases abroad by residents						
Purchases on the domestic territory by non-residents						
Value added at basic prices						
International Transport Margins						
Output at basic prices		Total intermediate output of region A	Total intermediate output of region B	Total final use output of region A	Total final use output of region B	

Figure 2: Schematic outline of a WIOT Analytic (for the case of two regions)

2.1.2 Environmental Satellite Accounts

Aside from replicating the basic economic structures contained in the World Input-Output Tables, the basic WIOD CGE model incorporates information from many of the environmental satellite accounts available in the WIOD database. The Basic WIOD CGE model implements information on energy use (broken down into a number of energy carriers), CO_2 emissions, and other emissions to air.[5] If required, further data available in the WIOD, for example on land use, material use or water use, can be implemented similarly, but is currently not included in the basic WIOD CGE model.

All satellite accounts consist of time series ranging from 1995 to 2009 and are provided in a sectoral aggregation consistent to WIOT's sectoral structure. They also include data on the final demand of private households.[6] Figure 3 gives a schematic representation of the WIOD satellite accounts.

Region	
Time	
	Air Emissions (AIR)
	Sources of CO_2 Emissions (CO2)
	Energy Use, Gross (EU)
	Energy Use, Emission Relevant (EM)
	Land Use (LAN)
	Material Use (MAT)
	Water Use (WAT)
WIOD Sectors	*Data*
Final Demand	*Data*
Totals	*Data*

Figure 3: Schematic representation of WIOD Emissions to Air (AIR), CO_2 Emissions (CO2), Energy Use, Gross (EU) and Energy Use, Emission Relevant (EM) tables, Land Use (LAN), Material Use (MAT) and Water Use (WAT).

We retrieve non-CO_2 air emission data for all WIOD sectors and final demand from the WIOD Emissions to Air tables (AIR). Carbon dioxide emissions are taken from the CO_2 Emissions tables (CO2). The data allows us to differentiate between energy-related and process related CO_2 emissions, which is of importance for climate policy analyses (Bednar-Friedl et al. 2012). Furthermore, to replicate the energy system in the WIOD CGE model, we draw on information from the WIOD Emission Relevant Energy Use tables (EM).

[5] With regard to non CO_2 emissions, WIOD includes N_2O, CH_4, NO_X, SO_X, NH_3, NMVOC, CO and it is planned to enlarge its scope of air emissions to SF_6, PFC, HFC, CFC, HCFC, HALON, CH_3Br, CH_3CCl_3.

[6] For more information regarding the WIOD environmental satellite accounts the interested reader is kindly referred to Timmer et al. (2012).

2.1.3 Substitution Elasticities

Elasticities are key parameters determining the comparative static behavior of economic models and thereby strongly influence the results of counterfactual policy analysis (Dawkins et al., 2001). Consequently, the choice of adequate elasticities is a crucial element in the development of all models. But despite their importance, the availability of consistent elasticities for CGE model appears to be unsatisfying. In particular only few estimates of elasticities of substitution suited for CGE modeling are available, e.g. Okagawa and Ban (2008), van der Werf (2008) and Kemfert (1998). This problem has also been tackled within the framework of the WIOD project. Exploiting the time series nature of the data, Koesler and Schymura (2012) estimate substitution elasticities for all sectors included in WIOD.[7] Their results are incorporated into the Basic WIOD CGE model. Thus the model uses substitution elasticities which are consistent to the data it is calibrated to.

2.2 Transfer XLSX to GDX

Originally all WIOD data is available as Microsoft Excel spread sheets. The WIOT Analytics are organised in 15 different files, each covering one year of the WIOD reporting period from 1995 to 2009. WIOD SEA, WIOD EM, WIOD CO2 and WIOD AIR are provided on a region specific basis, each including several worksheets covering one specific year. Other satellite accounts exhibit the same format.

As the Basic WIOD CGE model is implemented in the mathematical optimization program GAMS, the WIOD data needs to be transferred into the GAMS compatible data format GDX in order to make it available for the further data handling and modelling. In the process, all data points in the Excel spread sheets are transferred to the core data GDX file WIOD_PreAgg.gdx using the GAMS Data Exchange facilities. For example all variables associated with the intermediate use of products are integrated into the GDX parameter $Intermed_{r,i,rr,ii,t}$ with the dimensions r (region of origin), i (industry of origin), rr (importing region), i (importing industry) and t (year) and stored in the GDX data files.[8] A comprehensive overview of the notation used in the core GDX file is given in the Appendix. It is important to note that at this stage all data are transferred to the GDX file. Further aggregation and merging of the data is done at a later stage.

2.3 Aggregation of the Data

Originally, the WIOD data covers 40 regions plus ROW, 35 industries, 26 energy carriers and five forms of final demand. A complete list of regions, sectors and final demand types is given in the Appendix. Depending on the specific research question, it is important to balance the level of detail needed with the benefits of a small, highly aggregated database

[7]For more information regarding their estimation procedure and the results, the interested reader is referred to Koesler and Schymura (2012).

[8]Here and throughout the text, r alias rr or s stands for a region and i alias ii or j for a sector.

offering easier handling and interpretation in the light of economic theory. Choosing an adequate aggregation level is therefore an important step when preparing data for the use in numerical models.

To facilitate future policy analyses and research using the WIOD data and to ease the implementation of the desired aggregation level, we developed a simple but effective aggregation routine based on GAMS. It can be applied using the visual interface of the Java program WIODAgg developed by ZEW (Maznikova, 2011). This program enables researchers to easily implement any desired aggregation scheme to the WIOD data and produces the data file WIOD.gdx containing all aggregated values required by the Basic WIOD CGE model. The aggregation routine allows researchers to aggregate industries, regions, energy carriers, and final demand according to their proper needs. The elements of the core data file are summed up according to aggregation matrices specified by the researcher. As an example, Figure 4 gives a simplified illustration of the process when aggregating parameter $TotIntermed\_PreAgg_{(origR,origSec,t)}$ into two industries and two regions. $origR$ and $origSec$ denote the region and sector in the original WIOD data, prior to aggregation.

$$TotIntermed_{(t)} = flagAggSec^{-1} * TotIntermed\_PreAgg_{(t)} * flagAggR$$

with:

$$TotIntermed_{(t)} = \begin{pmatrix} TotIntermed_{(r,i,t)} & \cdots \\ \vdots & \ddots \end{pmatrix} \qquad i \times r$$

$$TotIntermed\_PreAgg_{(t)} = \begin{pmatrix} TotIntermed\_PreAgg_{(OrigR,OrigSec,t)} & \cdots \\ \vdots & \ddots \end{pmatrix} \qquad OrigSec \times OrigR$$

$$flagAggR = \begin{pmatrix} Agg_{(OrigR,r)} & \cdots \\ \vdots & \ddots \end{pmatrix} \text{ with } Agg_{(OrigR,r)} \in \{0,1\} \qquad OrigR \times r$$

$$flagAggSec = \begin{pmatrix} Agg_{(OrigSec,i)} & \cdots \\ \vdots & \ddots \end{pmatrix} \text{ with } Agg_{(OrigSec,i)} \in \{0,1\} \qquad OrigSec \times i$$

Figure 4: Illustration of general aggregation procedure.

Where substitution elasticities are concerned, we deviate from this procedure. In this case we weigh the respective substitution elasticities according to the value share of total output of an industry within the associated industry aggregate ($s_{(OrigR,OrigSec,r,i,t)}$) and sum up the corresponding elasticities using these shares. As a result of this procedure, although the substitution elasticities estimated by Koesler and Schymura (2012) feature no temporal or regional specification, the computed aggregate substitution elasticities may vary over time and space. This is due to the fact that the value shares of total output vary over time and space and this characteristic is conveyed to the aggregated substitution elasticities through the aggregation process. Figure 5 illustrates the aggregation procedure for substitution elasticities.

An important shortcoming of the WIOD dataset concerns the modelling of energy related sectors. Though the WIOD energy use data differentiates 26 energy carriers, current WIOT data does not allow for a detailed replication of the energy sector and

$$es\_kl\_KS_{(t)} = flagAggSec^{-1} * es\_kl\_KS\_PreAgg_{(t)} * flagAggR * Sec$$

with:

$$es\_kl\_KS_{(t)} = \begin{pmatrix} es\_kl\_KS_{(r,i,t)} & \cdots \\ \vdots & \ddots \end{pmatrix} \qquad i \times r$$

$$es\_kl\_KS\_PreAgg_{(t)} = \begin{pmatrix} es\_kl\_KS\_PreAgg_{(r,i,t)} * s_{(origR,origSec,r,i,t)} & \cdots \\ \vdots & \ddots \end{pmatrix} \qquad OrigSec \times OrigR$$

$$flagAggR = \begin{pmatrix} Agg_{(OrigR,r)} & \cdots \\ \vdots & \ddots \end{pmatrix} \text{ with } Agg_{(OrigR,r)} \in \{0,1\} \qquad OrigR \times r$$

$$flagAggSec = \begin{pmatrix} Agg_{(OrigSec,i)} & \cdots \\ \vdots & \ddots \end{pmatrix} \text{ with } Agg_{(OrigSec,i)} \in \{0,1\} \qquad OrigSec \times i$$

Figure 5: Illustration of the aggregation procedure for substitution elasticities.

thus the 26 energy carriers can only enter the model in a highly aggregated form. This results from the ambiguous specification of the industries in the original WIOT's. With respect to the energy systems this concerns in particular the industries Mining and Quarrying (C), Coke, Refined Petroleum and Nuclear Fuel (23), and Electricity, Gas and Water Supply (E). Subsuming the supply of coke, refined petroleum and nuclear fuel into one industry, for example, prohibits explicitly distinguishing between demand and supply for coke, refined petroleum products and nuclear fuel. To be able to replicate the individual energy usage of the industries in detail and to allow for the substitution of different energy carriers, information on the production and consumption flows within the energy system is imperative. We would like to stress that the Basic WIOD CGE model itself is capable of handling a wide range of energy commodities and as soon as the energy related industries are disaggregate. A proper replication of the energy sector is easily possible. But until then, the model distinguishes only between conventional (fossil fuels apart from gas) and alternative energy carriers (non fossil fuels and gas).

3 The Model

The model is a basic, static, multi-region, multi-sector CGE model replicating the production and distribution of commodities in the global economy. In line with the WIOD database and depending on the chosen aggregation scheme, it differentiates up to 40 regions plus ROW, 35 sectors and five forms of final demand. Figure 6 provides a diagrammatic overview of the basic economic structure of the model. The corresponding notation is given in the Appendix.

The model has been designed in such a way that it can easily be calibrated to any base year within the period from 1995 to 2009 according to the requirements of researchers. This is possible thanks to the panel character of the WIOD dataset and may help overcoming some of critique CGE models frequently face related to their calibration to one specific base year.

Following Rutherford and Arbor (2005) and Böhringer et al. (2003), the equilibrium

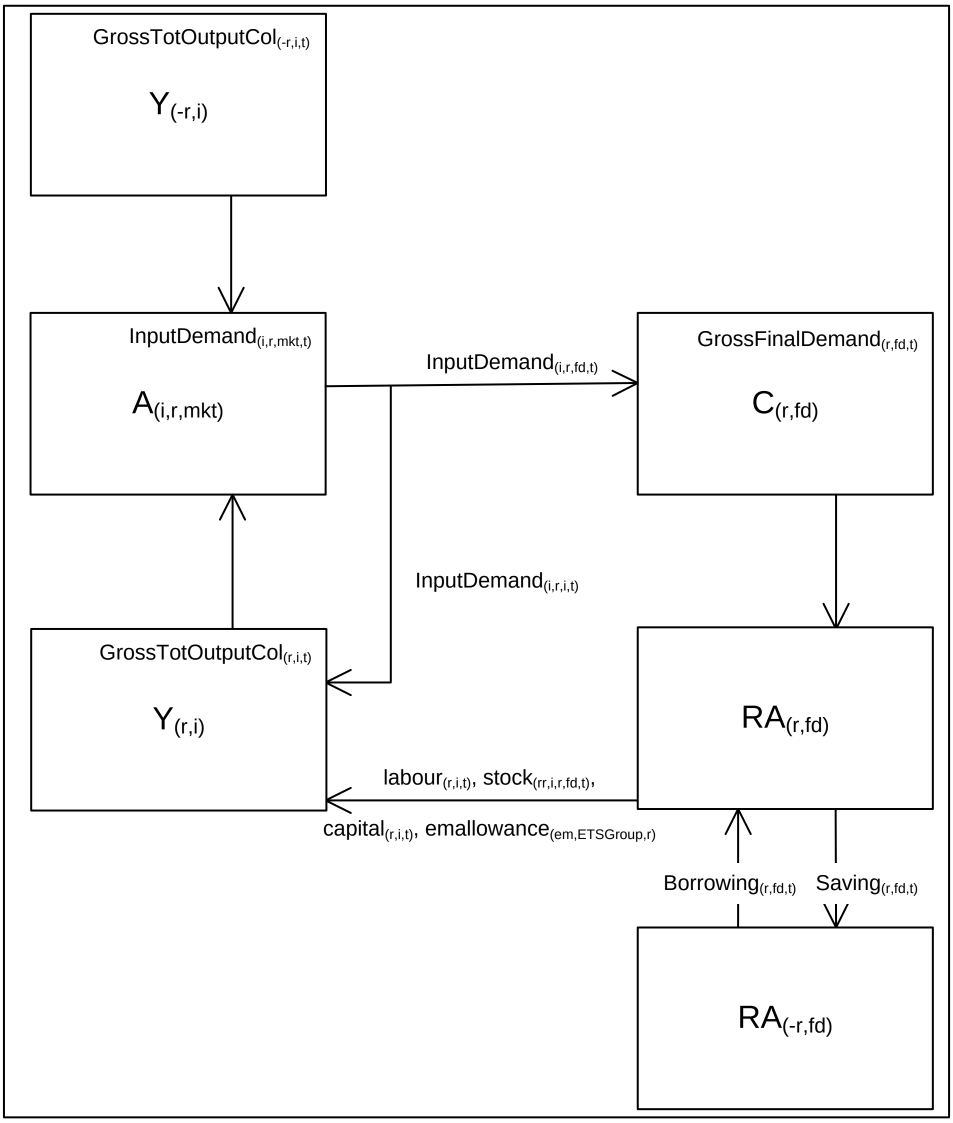

Figure 6: Basic Structure of WIOD CGE Model

is characterised through three types of equilibrium conditions, namely market clearance conditions for all commodities and factors (supply = demand), income balances (net income = net expenditure) and zero profit conditions (cost of inputs = value of output). The variables defining the equilibrium are activity levels for the constant-returns-to-scale production, commodity and factor prices, and the price of final consumption. In the basic model, we assume perfect competition on all markets and constant returns to scale.

Numerically, the model is formulated as a mixed complementarity problem (MCP) in the mathematical optimization program GAMS, a program that is frequently used to develop and run CGE models. It is written in GAMS using the MPSGE syntax (Rosenthal, 2010; Rutherford, 1999). The model is solved using the PATH algorithm (Dirkse and Ferris, 1995).

3.1 Commodity Production

The model distinguishes between two groups of commodities within the set i, energy commodities (set eg) and non-energy commodities (set neg). The production of all commodities $Y_{(r,i)}$ is captured by production functions characterizing technology through substitution possibilities between various energy, non-energy inputs and old stock of $Y_{(r,i)}$. Introducing stocks of $Y_{(r,i)}$ is necessary because of negative changes in inventories, represented by negative consumption, in the WIOT Analytics. They reflect the reduction of stocks and are interpreted as a perfect substitute to new $Y_{(r,i)}$ ($es\_stock_{(r,i)} = \text{inf}$).

Nested CES functions with five levels are employed to specify the substitution possibilities between labour, capital, energy inputs, non-energy intermediate inputs and existing stocks of $Y_{(r,i)}$. As described in Section 2.1.3, the corresponding substitution elasticities are taken from Koesler and Schymura (2012). To account for air emissions during commodity production (process and energy related emissions), the production structure is supplemented with Leontief nests capturing emissions during the production process.[9] While the following highlights crucial blocks of the commodity production structure, Figure 7 presents the production structure of the commodity production in detail. The corresponding zero-profit condition is illustrated in Equation 1. Throughout the text, π denotes profits and CES stands for a constant elasticity of substitution function. The arguments of the CES function is given in parentheses and the corresponding elasticity of substitution in the upper index.

[9] For more details regarding the modelling of air emission the interested reader is referred to Section 3.4 of this report.

$$
\begin{aligned}
\pi^{Y}_{(r,i)} \leq & CES^{\sigma^{es\_stock}_{(r,i,t)}}_{(r,i)} \Bigg[pstock_{(r,i,rr,FC\_HH)}, CES^{0}_{(r,i)} \Bigg[CES^{0}_{(r,i)}(pem_{(em,ETSGroup)}), \\
& CES^{\sigma^{klem}_{(r,i,t)}}_{(r,i)} \Big[CES^{\sigma^{ms}_{(r,i,t)}}_{(r,i)}(pa_{(neg,r,i)}), CES^{\sigma^{kle}_{(r,i,t)}}_{(r,i)} \big[CES^{\sigma^{e}_{(r,i,t)}}_{(r,i)}(pe\_em_{(eg,r,i)}), \\
& CES^{\sigma^{kl}_{(r,i,t)}}_{(r,i)}(pl_{(r)}, pk_{(r)}) \big] \Big] \Bigg] \Bigg]
\end{aligned}
\tag{1}
$$

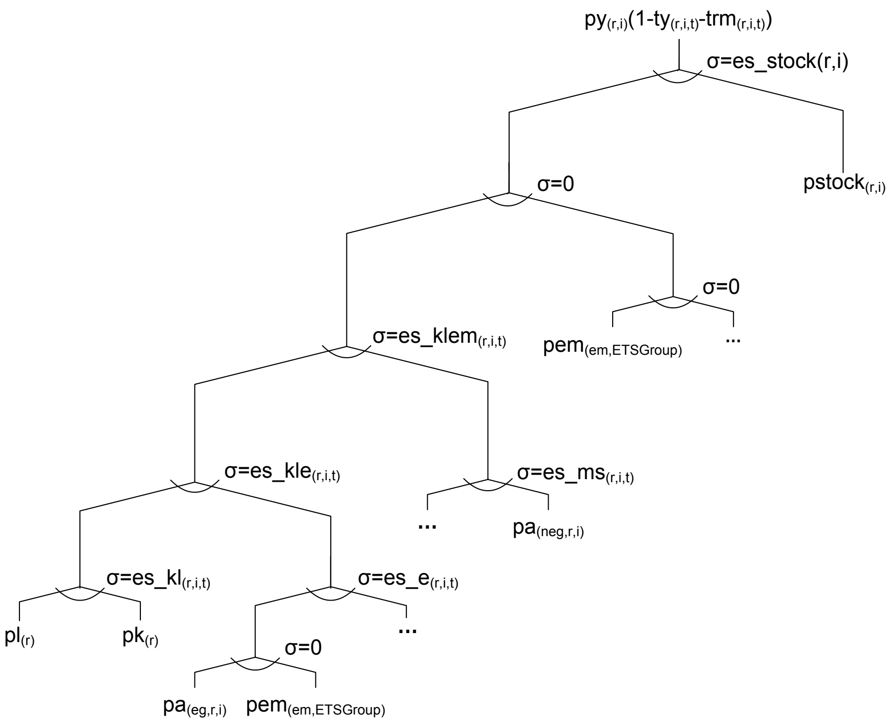

Figure 7: Structure of commodity production

At the top level of the production structure, a CES function describes the substitution possibilities between newly produced $Y_{(r,i)}$ and stocks of $Y_{(r,i)}$. Process emissions join the production in the second level. An aggregate of non-energy intermediate inputs enter in the third level. The fourth level describes the substitution possibilities between value added and energy. Finally, in separate nests in the fifth level of the CES production functions, labour and capital are combined to generate value added and energy is composed from a set of energy commodities. Total output $Y_{(r,i)}$ is taxed and transport margins are applied.[10]

3.2 Trade Structure

The model features up to 40 regions plus one aggregate for "Rest of the World" (ROW) to close the model. ROW is modelled as any other region in the model, the only exception

[10] For more information on taxes and transport margins, the interested reader is referred to Section 3.5 of this report.

being that no CO_2 or other air emissions are taken into account because no environmental information for ROW is available in the WIOD dataset.

According to the general equilibrium approach, in a static setting the trade between an individual region with all other regions should be balanced in the benchmark. Hence no trade deficits or surpluses should exist in the economy. But in practice this is rarely the case. Accordingly, when implementing the WIOD data, regions consume either more or less than their income would allow for. Therefore, budget surpluses and deficits occur regularly. To deal with these imbalances, international capital flows which equate the surpluses and deficits on a global level have to be modelled. Following Rutherford and Arbor (2005), we denominate the account deficits or surpluses with the consumption price of the numeraire region and adjust the endowments of the representative agents in order to match households' expenditures with their income.

Within the countries, the choice among imports and domestically produced commodities is based on Armington's idea of regional product differentiation (Armington, 1969). Domestic and foreign commodities are distinguished by origin and they are imperfect substitutes. Consequently, before the commodities can enter production as intermediates, an Armington composite $A_{(i,r,mkt)}$ is produced from domestic production and an import aggregate on the basis of a CES function. The import aggregate is a CES composite of all imports of a commodity composed in the second level of the Armington production function. WIOD does not feature any information on the substitutability of domestic and foreign commodities, as a consequence the corresponding Armington elasticities are set in the original version of the Basic WIOD CGE model to a fictive value ($es\_a_{(r,mkt,t)} = es\_mm_{(r,mkt,t)} = 5$). However, if deemed appropriate, Armington elasticities can easily be adjusted to appropriate levels.[11]

Each Armington composite is produced individually for the importing sectors or types of final demand in each region. Thereby, bisectoral and bilateral trade flows can be modelled specifically. This allows the WIOD CGE model to depict international trade in much greater detail than standard CGE models. Figure 8 displays the structures underlying the Armington aggregation. Equation 2 presents the corresponding zero-profit condition.

$$\pi^{A}_{(i,r,mkt)} \leq CES^{\sigma^{es\_a}_{(r,mkt,t)}}_{(i,r,mkt)} \left[py_{(r,i)}, CES^{\sigma^{es\_mm}_{(r,mkt,t)}}_{(i,r,mkt)} (py_{(rr,i)}) \right] \text{ with } rr \neq r \tag{2}$$

3.3 Final Demand

For each region, the model incorporates the behaviour of representative agents $RA_{(r,fd)}$ who in sum represent total final demand. In its standard version, the Basic WIOD CGE model includes at least a representative household FC_HH and a government agent GOV. If desired, the model can encompass all five forms of final demand supported by

[11] Armington elasticities are for example supplied within the GTAP 7 dataset (c.f. Badri and Walmsley, 2008).

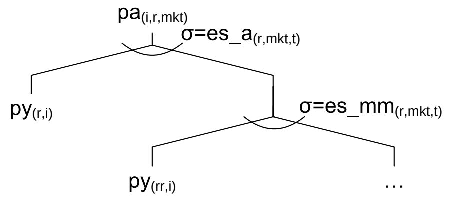

Figure 8: Structure of Armington aggregation

WIOD data or can subsume all final demand types in only one agent per region. In the standard version, FC_HH is endowed with the primary factors labour and capital, stocks of commodities (see subsection 3.1) and potentially emission allowances. Labour and capital are mobile across sectors within regions but cannot be traded between different regions. Commodity stocks are mobile across regions. In its basic version, the model abstracts from interregional factor mobility and investment. Government GOV receives income from taxes and possibly from selling emission allowances. As the budget of final demand agents need not be balanced in the benchmark, savings and borrowing adjust the budget appropriately and are incorporated as a fix additional endowment.

The behaviour of the representative agents can be described as choosing the bundle of consumption goods maximizing their individual utility taking into account their budget constraint. As described in Equations 3 and 4, their budget constraint is determined from factor income, tax revenues, revenues from the auctioning of emission allowances as well as by interregional and intertemporal saving or borrowing of the agent:

$$\begin{aligned} B_{(r,FC\_HH)} =& pk_{(r)} \sum_i \left(K_{(r,i)}\right) + pl_{(r)} \sum_i \left(L_{(r,i)}\right) + \sum_{rr} \sum_i \left(Stock_{(rr,i,r,FC\_HH)}\right) \\ &+ \alpha^{EMA}_{(r,FC\_HH)} EMA_{(em,ETSGroup)} \\ &- Saving_{(r,FC\_HH)} + Borrowing_{(r,FC\_HH)}, \end{aligned} \tag{3}$$

respectively

$$\begin{aligned} B_{(r,GOV)} =& Tax(r) + \alpha^{EMA}_{(r,GOV)} EMA_{(em,ETSGroup)} \\ &- Saving_{(r,GOV)} + Borrowing_{(r,GOV)}. \end{aligned} \tag{4}$$

where $EMA_{(em,ETSGroup)}$ denotes the value of emission allowances available in $ETSGroup$ and $\alpha^{EMA}_{(r,fd)}$ the share of $EMA_{(em,ETSGroup)}$ sold in region r by GOV or FC_HH. This approach allows for emissions trading systems spanning over more than one region.

Final demand of the representative agent is modelled as a constant elasticity of substitution (CES) composite combining energy with a non-energy Armington bundle. Energy is composed from a set of energy commodities on the basis of another CES function. Substitution patterns within the non-energy Armington bundle are also reflected via CES functions. As WIOD once more does not supply the corresponding elasticities, in the original Basic WIOD CGE model all three nests are reflected by Leontief functions ($es\_c_{(fd,r,t)} = es\_ca_{(fd,r,t)} = es\_ce_{(fd,r,t)} = 0$). But again, if deemed appropriate, the elasticites can easily be updated accordingly. Furthermore, to account for air emissions during consumption, Leontief nests capturing emissions from final demand are introduced.[12] Eventually total final demand $C_{(r,fd)}$ is taxed and transport margins are applied.[13] The structure underlying final demand is displayed in Figure 9. The corresponding zero-profit is presented in Equation 5.

$$\begin{aligned}\pi^{C}_{(fd,r)} \leq & CES^{0}_{(fd,r)}\Bigg[CES^{0}_{(r,fd)}\Bigg[CES^{\sigma^{es\_ca}_{(r,fd,t)}}_{(r,fd)}(pa_{(neg,r,fd)}), \\ & CES^{\sigma^{es\_ce}_{(r,fd,t)}}_{(r,fd)}(pe\_em_{(eg,r,fd)})\Bigg], CES^{0}_{(r,fd)}(pem_{(em,ETSGroup)})\Bigg]\end{aligned} \tag{5}$$

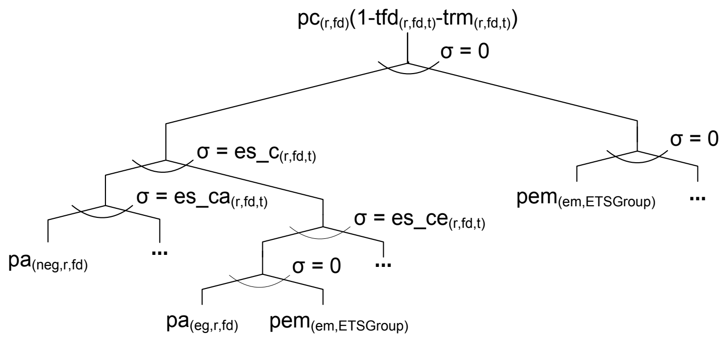

Figure 9: Structure of final demand

3.4 CO_2 and other Emissions

Besides the standard economic activity, the model makes provisions for the accounting of CO_2 and other air emissions caused by economic activity. According to Xepapadeas (2005) and Koesler (2010) there are three basic approaches of how pollution can be incorporated into an economic model. Firstly, emissions can be linked to the level of private consumption. In such a setting emissions can be seen as a by-product of consumption and final demand is directly responsible for determining how much pollution is generated in the economy. Secondly, emissions can be related to the production process, such that pollution is a necessary by-product of production. In this context, the production sectors are directly responsible of how much emissions are generated, although they have only an indirect influence on emissions by choosing their level of output. Both approaches would imply determining the prevailing amount of emissions in a model by combining consumption respectively output with a fixed factor outside the actual optimisation problems of the agents. But, while this would enable the model

[12]For more details regarding the modelling of air emission the interested reader is referred to Section 3.4 of this report.

[13]For more information on taxes and transport margins, the interested reader is referred to Section 3.5 of this report.

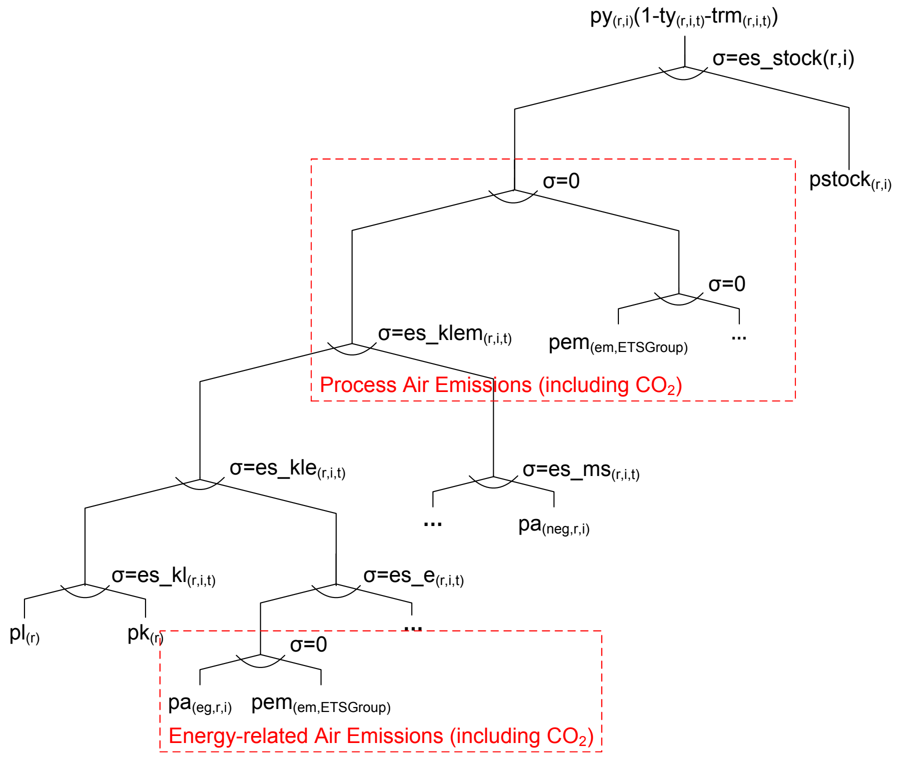

Figure 10: Air emissions from commodity production

to account for emissions, it would do so in a rather passive manner and emissions would have no direct effect on the agents' behaviour.

As a third possibility, emissions may arise because they are needed as an input in the production process for the goods traded in the economy. Here, the producing sectors decide directly how much pollution will prevail in the economy by choosing which inputs they use and what amount of output they will produce. Following the recent CGE literature, we model emissions as the fictive necessary input $pem_{(em,ETSGroup)}$ into the production of commodities and the consumption good. While the fictive input is supplied by the representative agent $GOV_{(r)}$, it is paired with the input causing the emission in a Leontief nest in the respective production function. Setting the endowment of $pem_{(em,ETSGroup)}$ sufficiently large implies the supply of the fictive input to outnumber demand as long as no regulation is assumed for. Hence, if emissions are not taxed, the production costs induced by the usage of the fictive input are zero. Furthermore, $pem_{(em,ETSGroup)}$ is mobile between all sectors assigned to a group within the set ETSGroup.

As far as CO_2 emissions are concerned, the model distinguishes between energy related CO_2 emissions (arising due to the burning of fossil fuels) and process emissions (e.g. caused during the production of cement). With respect to other air emissions (N_2O, CH_4, NO_X, SO_X, NH_3, NMVOC, CO), we also take into account that in principle these emissions can emerge as a result of the general production process (process emissions) as well as from energy-related processes. But at present the WIOD data does not allow for a distinction between energy related air emissions and air emissions related to general production because it includes only one general air emission data file for emissions regardless of their origin. To overcome this problem, WIOD air emissions data should be assigned to their respective point of origin, similar to the WIOD CO_2 Emission files which attribute CO_2 emissions to their source.

This discussion is of particular interest, as the modeller has to decide with which input he associates the different pollutant, in our case emissions. Let us take CO_2 as an example. The majority of CO_2 arises from the burning fossil fuels and should be linked to the energy input. But a certain share of CO_2 emissions is generated as process emissions, for example in cement or steel production. Hence CO_2 emissions should be assigned to different parts in the production structure. Bednar-Friedl et al. (2012) show that differentiating between energy-related and process emissions is of importance for climate policy.

The case is more complicated for other air pollutants for whom emissions cannot be calculated as straightforwardly as for CO_2. Emissions of NO_x, for example, also occur when burning fossil fuels. Their amount can be reduced by modifying the burning process or by end-of-pipe measures. This is not possible for CO_2.

Modelling pollutants other than carbon dioxide is beyond the scope of the basic WIOD CGE model and needs further information. We only distinguish between energy and process emissions of CO_2 and treat all other air pollutants as process emissions arising with from the general production process. However, the Basic WIOD CGE model has been modelled in such a way that modellers can easily implement a split in energy and process emissions for all air emission types if desired and the corresponding data is available.

From a modelling perspective, when emissions are related to energy consumption, they enter the production process parallel to the input energy. That is to say, the respective emissions build with energy an energy-emission composite on the basis of fix input shares which is then employed in the standard production process. Input shares $EmissionPerUnit_{(em,"co2energy"r,mkt,t)}$ vary depending on the type of accompanied energy good and are determined according to

$$EmissionPerUnit_{(em,co2energy,r,mkt,t)} = \frac{Emission_{(em,co2energy,r,mkt,t)}}{InputDemand_{(eg,r,mkt,t)}}. \quad (6)$$

The modelling of process emissions is carried out along the same lines, with the exception that process emissions appear only in the production in the top nest of the production function. Figure 10 highlights the relevant nests in the structure of the commodity production. Figure 11 does the same for the production of the consumption good.

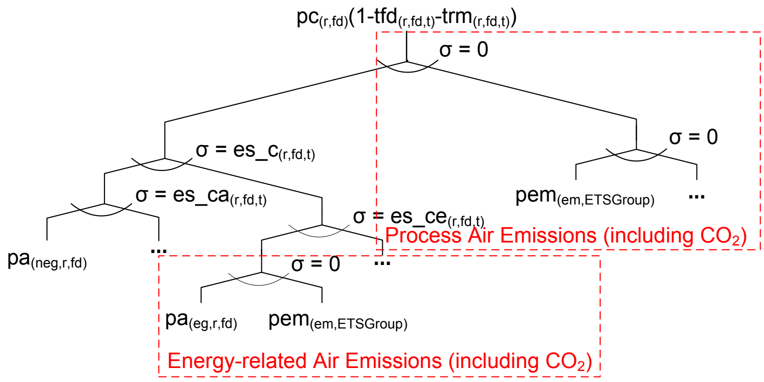

Figure 11: Air emissions from final demand

3.5 Taxes and International Transport Margins

Besides consumption and production flows as well as air emissions, the model also replicates the existing tax structure as well as international transport margins in a specific benchmark year. But in the current version of the WIOT Analytics taxes and international trade margins are supplied only in the form of separate rows below the WIOD Input-output table. Taxes have not been divided by product or final demand and international trade margins are not allocated to the region/industry responsible for the delivery of these services.[14] As a result, no realistic tax, tariff and transport structure can be incorporated into the model because taxes and transport margins can only be assigned globally to the sector paying them. Given this problem of the presently available WIOD data, we model all taxes and transport margins as an ad valorem tax on the production of commodities and consumption goods. Note that the WIOD data also does not feature tariffs or input and factor taxes. Nevertheless, in order to allow for a simple extension of the basic model, we include input taxes $ti_{(r,i,t)}$ and factor taxes $tf_{(r,i,t)}$ in the commodity production structure, although in the benchmark these are set to be zero. In the basic WIOD CGE model all tax income generated in region r is assigned to the government $GOV_{(r)}$.

3.6 Climate Policy

In order to allow for a first application of the Basic WIOD CGE model, we have implemented basic climate policies and allow each air emission to be regulated by means of an emission trading scheme. As described in Section 3.4, emissions are modelled as an input $pem_{(em,ETSGroup)}$ into the production of commodities and the consumption good. This additional input can be interpreted as an emission allowance. By assigning sectors and consumption to a group whose members all use the same type of input, respectively allowance, one can implement a trading group encompassing a set of sectors and

[14]For more information the interested reader is referred to Timmer et al. (2012).

final demands subject to a common emission trading scheme. We assume that emission allowances $EMA_{(em,ETSGroup)}$ are auctioned by $GOV_{(r)}$ or $FC\_HH_{(r)}$.

Originally, the price for allowances is zero as long as the supply of allowances by $GOV_{(r)}$ is equal or bigger than demand. When capping their supply, the price of emission allowance becomes positive. In this case allowances become an ordinary (costly) input into production. In this spirit we have incorporated into the model the parameter $EmissionRdcTarget_{(em,ETSGroup,t)}$. It expresses the reduction targets for a certain group of sectors defined within the set $ETSGroup$, relative to the benchmark emissions.

This effectively implements an emission trading scheme in the model. By choosing different emission reduction targets and assigning sectors to different trading groups one can effectively simulate different emission trading regimes.

3.7 Market Clearance Conditions

Finally, in equilibrium, a set of market clearance conditions must hold. The market clearance condition for domestic production is given by:

$$\begin{aligned} Y_{(r,i)} \geq & \sum_{ii} \left(\frac{\partial \pi^Y_{(r,ii)}}{\partial py_{(r,i)}} Y_{(r,ii)} \right) + \sum_{fd} \left(\frac{\partial \pi^C_{(r,fd)}}{\partial py_{(r,i)}} C_{(r,fd)} \right) \\ & + \sum_{rr;r \neq rr} \left(\frac{\partial \pi^M_{(rr,i)}}{\partial py_{(r,i)}} M_{(rr,i)} \right) - \sum_{rr} \left(Stock_{(r,i,rr,FC\_HH)} \right), \end{aligned} \tag{7}$$

where $Y_{(r,i)}$ is the value of domestic production, $C_{(r,i)}$ the value of domestic final demand, $M_{(r,i)}$ the value of imports by foreign regions, and $Stock_{(r,i,rr,FC\_HH)}$ the value of commodities stocked by households. The clearance of international commodity markets demand:

$$M_{(r,i)} \geq \sum_{rr;rr \neq r} \left(\frac{\partial \pi^M_{(rr,i)}}{\partial pm_{(r,i)}} Y_{(rr,i)} \right). \tag{8}$$

Factor markets clear if:

$$K_{(r,i)} \geq \sum_{ii} \left(\frac{\partial \pi^Y_{(r,ii)}}{\partial pk_{(r)}} Y_{(r,ii)} \right), \tag{9}$$

and

$$L_{(r,i)} \geq \sum_{ii} \left(\frac{\partial \pi^Y_{(r,ii)}}{\partial pl_{(r)}} Y_{(r,ii)} \right). \tag{10}$$

The market for emission allowances is cleared if:

$$\begin{aligned} EMA_{(em,ETSGroup)} \geq & \sum_{r} \sum_{i} \left(\frac{\partial \pi^Y_{(r,i)}}{\partial pem_{(em,ETSGroup)}} Y_{(r,i)} \right) \\ & + \sum_{r} \sum_{fd} \left(\frac{\partial \pi^C_{(r,fd)}}{\partial pem_{(em,ETSGroup)}} C_{(r,fd)} \right), \end{aligned} \tag{11}$$

To ensure that markets for the consumer goods clear the following must hold:

$$B_{(r,fd)} \geq C_{(r,fd)}. \tag{12}$$

4 Summary

This report presents the Basic WIOD CGE model. The model represents the first implementation of the novel World Input-Output Database (WIOD) into the computable general equilibrium (CGE) framework and is tailored to provide a maximum fit with the available WIOD data. The model is set up as a basic, static, multi-region, multi-sector CGE model which replicates the production and distribution of commodities in the global economy. The data preparation facilities and model are designed deliberately as flexible as possible in order to allow researchers to use them as a basis for various applications.

The Baisc WIOD CGE model incorporates key features of WIOD including: bilateral and bisectoral trade flows, satellite accounts for different types of energy consumption and greenhouse gas as well as other emissions to air on a sectoral level. Thereby all required data stems from one consistent database. As all WIOD data is available in the form of a consistent time series ranging from 1995 to 2009, the model can be calibrated to any year within this time period. For substitution elasticities, the Basic WIOD CGE model relies on parameters which are consistently estimated from the same dataset the model itself is calibrated to.

Given the comprehensive coverage of bilateral and bisectoral trade flows, the detailed information on energy use and its potential to account for various types of environmental aspects of economic activity, the Basic WIOD CGE model seems particularly potent in serving as as the basis for research in fields of energy and environmental policy or trade policy. Overall, the Basic WIOD CGE model enables researchers to secure the numerous advantages of the WIOD dataset when using CGE models for future research.

5 Note

To allow interested researchers to use the WIOD data within the mathematical optimization program GAMS, this presentation of the Basic WIOD CGE model is accompanied by a GDX file including all the WIOD data required within the context of the WIOD CGE model (Version: 14.4.2013). Moreover, we supply an aggregation routine which enables researchers to tailor the WIOD data depending on their needs. The corresponding ZIP file is available at www.zew.de/WIODAgg2013. When using these files, a reference should be made to this document as well as to Timmer et al. (2012) and Dietzenbacher et al. (2013). Please note that no support will be provided for the files, no guarantee is provided regarding the validity of the data and all consequences of using the files are solely in the responsibility of the person using them.

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A Appendix

Table 1: List of data sources used to generate WIOD.gdx

Short	Data Source
WIOT Analytics	World Input-Output Tables
SEA	Socio-Economics Accounts
AIR	Emissions to Air
CO2	CO_2 Emissions
EU	Energy Use
EM	Energy Use Emission Relevant
KS	Koesler and Schymura (2012)

Table 2: List of regions, sectors and final demand types in WIOD

Short	Region	Short	Sector or Final Demand
AUS	Australia	AtB	Agriculture, Hunting, Forestry and Fishing
AUT	Austria	C	Mining and Quarrying
BEL	Belgium	15t16	Food, Beverages and Tobacco
BGR	Bulgaria	17t18	Textiles and Textile Products
BRA	Brasil	19	Leather, Leather and Footwear
CAN	Canada	20	Wood and Products of Wood and Cork
CHN	China	21t22	Pulp, Paper, Paper , Printing and Publishing
CYP	Cyprus	23	Coke, Refined Petroleum and Nuclear Fuel
CZE	Czech Republic	24	Chemicals and Chemical Products
DEU	Germany	25	Rubber and Plastics
DNK	Denmark	26	Other Non-Metallic Mineral
ESP	Spain	27t28	Basic Metals and Fabricated Metal
EST	Estland	29	Machinery, Nec
FIN	Finland	30t33	Electrical and Optical Equipment
FRA	France	34t35	Transport Equipment
GBR	Great Britain	36t37	Manufacturing, Nec; Recycling
GRC	Greece	E	Electricity, Gas and Water Supply
HUN	Hungaria	F	Construction
IDN	Indonesia	50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
IND	India	51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
IRL	Ireland	52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
ITA	Italia	H	Hotels and Restaurants
JPN	Japan	60	Inland Transport
KOR	South Korea	61	Water Transport
LTU	Lithuania	62	Air Transport
LUX	Luxemburg	63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
LVA	Latvia	64	Post and Telecommunications

Table 2: List of regions, sectors and final demand types in WIOD

Short	Region	Short	Sector or Final Demand
MEX	Mexico	J	Financial Intermediation
MLT	Malta	70	Real Estate Activities
NLD	The Netherlands	71t74	Renting of M&Eq and Other Business Activities
POL	Poland	L	Public Admin and Defence; Compulsory Social Security
PRT	Portugal	M	Education
ROM	Romania	N	Health and Social Work
RUS	Russia	O	Other Community, Social and Personal Services
SVK	Slovakia	P	Private Households with Employed Persons
SVN	Slovenia		
SWE	Sweden	FC_HH	Final consumption expenditure by households
TUR	Turkey	FC_NP	Final consumption expenditure by non-profit organisations serving households (NPISH)
TWN	Taiwan	FC_GOV	Final consumption expenditure by government
USA	United Staates of America	FC_CF	Gross fixed capital formation
RoW	Rest of the World	FC_IV	Changes in inventories and valuables

Table 3: Elements in core data file WIOD.gdx

Element	Description	Source	Unit
$CiffobAdj_{(r,mkt,t)}$	Cif fob adjustments on exports	WIOT Analytics	current mio. US Dollar
$Capital_{(r,i,t)}$	Computed absolute values for capital compensation	WIOT Analytics	current mio. US Dollar
$Labor_{(r,i,t)}$	Computed absolute values for labor compensation	WIOT Analytics	current mio. US Dollar
$DirPur_{(r,fd,t)}$	Direct purchases abroad by residents	WIOT Analytics	current mio. US Dollar
$FinalDemand_{(r,i,rr,fd,t)}$	Final demand inputs and outputs	WIOT Analytics	current mio. US Dollar
$Intermed_{(r,i,rr,ii,t)}$	Intermediate inputs and outputs	WIOT Analytics	current mio. US Dollar
$IntTransMa_{(r,mkt,t)}$	International Transport Margins	WIOT Analytics	current mio. US Dollar
$TotOutputCol_{(r,mkt,t)}$	Output at basic prices in columns	WIOT Analytics	current mio. US Dollar
$TotOutputRow_{(r,i,t)}$	Output at basic prices in rows	WIOT Analytics	current mio. US Dollar
$PurNonRes_{(r,fd,t)}$	Purchases on the domestic territory by non-residents	WIOT Analytics	current mio. US Dollar
$TaxFinalDemand_{(r,fd,t)}$	Taxes less subsidies on final demand	WIOT Analytics	current mio. US Dollar
$TaxOutput_{(r,i,t)}$	Taxes less subsidies on products	WIOT Analytics	current mio. US Dollar
$TotIntermed_{(r,mkt,t)}$	Total intermediate consumption	WIOT Analytics	current mio. US Dollar
$ValueAdded_{(r,i,t)}$	Value added compensation at basic price	WIOT Analytics	current mio. US Dollar
$es\_kl\_KS_{(r,i,t)}$	Elasticity of substitution between K and L	KS	
$es\_kle\_KS_{(r,i,t)}$	Elasticity of substitution between KL and E	KS	
$es\_klem_{K}S_{(r,i,t)}$	Elasticity of substitution between KLE and MS	KS	
$es\_ms\_KS_{(r,i,t)}$	Elasticity of substitution between M and S	KS	
$EM\_Sec_{(eg,r,i,t)}$	Emission relevant energy use of industries	EM	Terajoules
$EM\_FD_{(eg,r,fd,t)}$	Emissions relevant energy use of final demand	EM	Terajoules
$EM\_Total_{(eg,r,t)}$	Total emissions relevant energy use per energy carrier	EM	Terajoules
$EU\_Sec_{(eg,r,i,t)}$	Energy use of industries	EU	Terajoules
$EU\_FD_{(eg,r,fd,t)}$	Energy use of final demand	EU	Terajoules
$EU\_Total_{(eg,r,t)}$	Total energy use per energy carrier	EU	Terajoules
$CO2FD_{(co2source,r,fd,t)}$	CO2 emissions per final demand	CO2	Kilotons
$CO2Sec_{(co2source,r,i,t)}$	CO2 emissions per sector	CO2	Kilotons
$CO2Total_{(co2source,r,t)}$	Total CO2 emissions per source	CO2	Kilotons

Table 3: Elements in core data file WIOD.gdx

Element	Description	Source	Unit
$AirSec_{(em,r,i,t)}$	Air emissions of sector	AIR	Tons (CO_2 in Kilotons)
$AirFD_{(em,r,fd,t)}$	Air emissions of final demand	AIR	Tons (CO_2 in Kilotons)
$TotAirFD_{(em,r,t)}$	Total air emissions of final demand	AIR	Tons (CO_2 in Kilotons)
$TotAirSec_{(em,r,t)}$	Total air emissions of sector	AIR	Tons (CO_2 in Kilotons)
$TotAir_{(em,r,t)}$	Total air emissions of sectors and final demand	AIR	Tons (CO_2 in Kilotons)
$LABShare_{(origR,origSec,t)}$	Labor share		
$SecShare_{(origR,origSec,r,i,t)}$	Output share		
$aggE_{(origE,eg)}$	Set – Aggregation of energy carriers		
$aggFD_{(origFD,fd)}$	Set – Aggregation of final demand		
$aggMKT_{(origMKT,mkt)}$	Set – Aggregation of markets		
$aggR_{(origR,r)}$	Set – Aggregation of regions		
$aggSec_{(origSec,i)}$	Set – Aggregation of sectors		
$aggco2src_{(co2src,co2source)}$	Set – Aggregation of sources for CO2 emission		
mkt	Set – All markets - sectors plus final demands		
em	Set – Emissions to Air		
$eg(mkt)$	Set – Energy goods		
$fd(mkt)$	Set – Final demand		
r, alias rr, s	Set – regions		
$i(mkt)$, alias ii, j	Set – sectors to be used in the model		
$co2source$	Set – Sources of CO_2 emissions		
t	Set – time		

Table 4: Elements in core data file WIOD_PreAgg.gdx

Element	Description	Source	Unit
$CAP\_SEA\_PreAgg_{(origR,origSec,t)}$	Absolute values for capital compensation from YL files	SEA	current mio. local currency
$LAB\_SEA\_PreAgg_{(origR,origSec,t)}$	Absolute values for labor compensation from YL files	SEA	current mio. local currency
$VA\_SEA\_PreAgg_{(origR,origSec,t)}$	Absolute values for value added from YL files	SEA	current mio. local currency
$CiffobAdj\_PreAgg_{(r,mkt,t)}$	Cif fob adjustments on exports	WIOT Analytics	current mio. US Dollar
$DirPur\_PreAgg_{(r,fd,t)}$	Direct purchases abroad by residents	WIOT Analytics	current mio. US Dollar
$FinalDemand\_PreAgg_{(r,i,rr,fd,t)}$	Final demand inputs and outputs	WIOT Analytics	current mio. US Dollar
$Intermed\_PreAgg_{(r,i,rr,ii,t)}$	Intermediate inputs and outputs	WIOT Analytics	current mio. US Dollar
$IntTransMa\_PreAgg_{(r,mkt,t)}$	International Transport Margins	WIOT Analytics	current mio. US Dollar
$TotOutputCol\_PreAgg_{(r,mkt,t)}$	Output at basic prices in columns	WIOT Analytics	current mio. US Dollar
$TotOutputRow\_PreAgg_{(r,i,t)}$	Output at basic prices in rows	WIOT Analytics	current mio. US Dollar
$PurNonRes\_PreAgg_{(r,fd,t)}$	Purchases on the domestic territory by non-residents	WIOT Analytics	current mio. US Dollar
$TaxFinalDemand\_PreAgg_{(r,fd,t)}$	Taxes less subsidies on final demand	WIOT Analytics	current mio. US Dollar
$TaxOutput\_PreAgg_{(r,i,t)}$	Taxes less subsidies on products	WIOT Analytics	current mio. US Dollar
$TotIntermed\_PreAgg_{(r,mkt,t)}$	Total intermediate consumption	WIOT Analytics	current mio. US Dollar
$ValueAdded\_PreAgg_{(r,i,t)}$	Value added compensation at basic price	WIOT Analytics	current mio. US Dollar
$es\_kl_KS\_PreAgg_{(r,i,t)}$	Elasticity of substitution between K and L	KS	
$es\_kle_KS\_PreAgg_{(r,i,t)}$	Elasticity of substitution between KL and E	KS	
$es\_klem_KS\_PreAgg_{(r,i,t)}$	Elasticity of substitution between KLE and MS	KS	
$es\_ms_KS\_PreAgg_{(r,i,t)}$	Elasticity of substitution between M and S	KS	
$EM\_Sec\_PreAgg_{(eg,r,i,t)}$	Emission relevant energy use of industries	EM	Terajoules
$EM\_FD\_PreAgg_{(eg,r,fd,t)}$	Emissions relevant energy use of final demand	EM	Terajoules
$EM\_Total\_PreAgg_{(eg,r,t)}$	Total emissions relevant energy use per energy carrier	EM	Terajoules
$EU\_Sec\_PreAgg_{(eg,r,i,t)}$	Energy use of industries	EU	Terajoules
$EU\_FD\_PreAgg_{(eg,r,fd,t)}$	Energy use of final demand	EU	Terajoules
$EU\_Total\_PreAgg_{(eg,r,t)}$	Total energy use per energy carrier	EU	Terajoules
$CO2FD\_PreAgg_{(co2source,r,fd,t)}$	CO2 emissions per final demand	CO2	Kilotons
$CO2Sec\_PreAgg_{(co2source,r,i,t)}$	CO2 emissions per sector	CO2	Kilotons

Table 4: Elements in core data file WIOD_PreAgg.gdx

Element	Description	Source	Unit
$CO2Total\_PreAgg_{(co2source,r,t)}$	Total CO2 emissions per source	CO2	Kilotons
$AirSec\_PreAgg_{(em,r,i,t)}$	Air emissions of sector	AIR	Tons (CO_2 in Kilotons)
$AirFD\_PreAgg_{(em,r,fd,t)}$	Air emissions of final demand	AIR	Tons (CO_2 in Kilotons)
$TotAirFD\_PreAgg_{(em,r,t)}$	Total air emissions of final demand	AIR	Tons (CO_2 in Kilotons)
$TotAirSec\_PreAgg_{(em,r,t)}$	Total air emissions of sector	AIR	Tons (CO_2 in Kilotons)
$TotAir\_PreAgg_{(em,r,t)}$	Total air emissions of sectors and final demand	AIR	Tons (CO_2 in Kilotons)
em	Set – Emissions to Air		
$origFD(origMKT)$	Set – Original final demand of goods in WIOD		
$origSec(origMKT)$	Set – Original industries in WIOD (35 industry level)		
$origMKT$	Set – Original markets in WIOD (industries and final consumption)		
$origR$	Set – Original Regions		
$origE$	Set – Original types of energy in WIOD		
$co2src$	Set – Original sources of CO_2 emission		
t	Set – time		

Table 5: Notation in Basic WIOD CGE Model

Element	Description
$A_{(i,r,mkt)}$	Armington composite production
$es\_a_{(r,mkt,t)}$	Armington elasticity of substitution between import composite and domestic commodity
$es\_mm_{(r,mkt,t)}$	Armington elasticity of substitution between imports of different countries
$Borrowing_{(r,fd,t)}$	Borrowing of final demand agents
$Saving_{(r,fd,t)}$	Saving of final demand agents
$Y_{(r,i)}$	Commodity production
$C_{(r,fd)}$	Consumption good production
$EmissionRdcTarget_{(em,ETSGroup,t)}$	Emission reduction target
$EmissionPerUnit_{(em,co2energy,r,mkt,t)}$	Emissions per unit of energy use (energy related emissions) or per unit of output (process emissions)
$GOV_{(r)}$	Final demand agent – government
$FC\_HH_{(r)}$	Final demand agent – representative household
$flaggAggR$	Flag used in the regional aggregation process
$flaggAggSec$	Flag used in the sectoral aggregation process
$pa_{(i,r,mkt)}$	Price of Armington good
$pk_{(r)}$	Price of capital
$py_{(i,r)}$	Price of commodity
$pem_{(em,ETSGroup)}$	Price of emission
$pe_{e}m_{(eg,r,fd)}$	Price of energy good
$pc_{(r,fd)}$	Price of final demand
$pl_{(r)}$	Price of labour
$pstock_{(r,i,rr,"FC\_HH")}$	Price of old stock
$RA_{(r,fd)}$	Representative agent
mkt	Set – All markets - sectors plus final demands
$co2energy(co2source)$	Set – CO_2 sources related to energy emissions
$ETSGroup$	Set – Emission trading groups
em	Set – Emissions to Air
$eg(mkt)$	Set – Energy goods

Table 5: Notation in Basic WIOD CGE Model

Element	Description
$fd(mkt)$	Set – Final demand
$neg(mkt)$	Set – Non-energy goods
r, alias rr, s	Set – regions
$i(mkt)$, alias ii, j	Set – sectors
$co2source$	Set – Sources of CO_2 emissions
$Process$	Set – Sources related to process emissions
t	Set – time
$es\_kl_{(r,i,t)}$	Substitution elasticity between capital and labour in commodity production
$es\_kle_{(r,i,t)}$	Substitution elasticity between capital-labour composite and energy in commodity production
$es\_klem_{(r,i,t)}$	Substitution elasticity between capital-labour-energy composite and other intermediated goods in commodity production
$es\_e_{(r,i)}$	Substitution elasticity between different energy goods in commodity production
$es\_ce_{(r,t)}$	Substitution elasticity between different energy goods of final demand agents
$es\_ms_{(r,i,t)}$	Substitution elasticity between different non-energy Armington goods in commodity production
$es\_c_{(r,t)}$	Substitution elasticity between energy and other goods of final demand agents
$es\_stock_{(r,i,t)}$	Substitution elasticity between newly produced commodities and old stock in commodity production
$t\_f_{(r,i,t)}$	Tax – factor
$t\_i_{(r,i,t)}$	Tax – input
$TotIntermed_{(r,i,t)}$	Vale of total intermediates used in benchmark
$capital_{(r,i,t)}$	Value of capital used in production of commodity
$emAllowance_{(em,ETSGroup,r)}$	Value of emission allowances
$GrossFinalDemand_{(r,fd,t)}$	Value of gross final demand
$GrossTotOutputCol_{(r,i,t)}$	Value of gross total output
$labour_{(r,i,t)}$	Value of labour employed in production of commodity
$stock_{(rr,i,r,fd,t)}$	Value of old stock of final demand agent fd in region r used in production of commodity i in region rr in benchmark t
$InputDemand_{(i,r,mkt,t)}$	Value of the sum of all intermediates employed in the commodity production or final demand

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- Informationsvermittlung,
- Wissenstransfer und Weiterbildung.

Im Rahmen der Projektforschung werden weltwirtschaftliche Entwicklungen und insbesondere die mit der europäischen Integration einhergehenden Veränderungsprozesse erfaßt und in ihren Wirkungen auf die deutsche Wirtschaft analysiert. Priorität besitzen Forschungsvorhaben, die für Wirtschaft und Wirtschaftspolitik praktische Relevanz aufweisen. Die Forschungsergebnisse werden sowohl im Wissenschaftsbereich vermitteltals auch über Publikationsreihen, moderne Medien und Weiterbildungsveranstaltungen an Unternehmen, Verbände und die Wirtschaftspolitik weitergegeben.
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- Internationale Verteilungsanalysen,
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