E3.KZ MODEL HANDBOOK

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Policy Advice for Climate Resilient Economic Development

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On behalf of
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)

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E3.KZ MODEL HANDBOOK
Update 2025

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List of abbreviations

CGE	Computable General Equilibrium
CHP	Combined heat and power
CMIP	Coupled Model Intercomparison Projects
CRED	Climate Resilient Economic Development
COMSTAT	Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan
CORDEX	Coordinated Regional Climate Downscaling Experiment
CPA	Statistical classification of products by activity
DIM	Disaster Impact Model
DIOM-X	Dynamic Input-Output Models in Excel
E3	Economy, Energy, Emissions
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GRP	Gross regional product
GVA	Gross Value Added
GWS	Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung)
IAM	Integrated Assessment Model
IEA	International Energy Agency
INFORUM	INterindustry FORecasting at the University of Maryland
IO	Input-output
IOT	Input-output table
MS Excel	Microsoft Excel
NACE	Classification of industries (Nomenclature statistique des activités économiques dans la Communauté européenne)
NPISH	Non-profit institutions serving households
NUTS	Nomenclature des unités territoriales statistiques
OLS	Ordinary least squares
SNA	System of National Accounts
SOCLIMPACT	DownScaling CLImate imPACTs
SSP	Shared Socioeconomic Pathways
ToPDAd	Tool-supported policy development for regional adaptation
TPES	Total primary energy supply
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VBA	Visual Basic for Applications

HOW TO...?

This section provides a brief description of the most important steps that may arise when updating and upgrading the e3.kz model. These steps are explained in greater detail in subsequent sections of the model handbook. The blue arrows show mandatory steps, the turquoise arrows indicate steps that are optional (depending on the context).

REMEMBER ALWAYS: SAVE YOUR CHANGES!

[How to] Update data for an existing model variable

1. **Update the Lastdata** entry on the *Dataset* sheet for the respective variable according to the last available historical data point
2. **Add new data** on the *Values* sheet for the respective variable and respective year
3. **Press the *Run* button** on the *Model* sheet and finally,
4. **Check** if the new data point is shown in the *Results* sheet

[How to] Add a new model variable

1. **Add** a unique **variable name** at the end of the list on the *Dataset* sheet
   IMPORTANT: consider naming convention

2. Add **mandatory properties** on the *Dataset* sheet (number of row(s), column(s) and Lastdata)

3. Add **descriptive properties** on the *Dataset* sheet
   a) Variable description (in English), unit, date of last revision, data source)
   b) For vector (and matrix) variables add a row (and column) description
   c) If not yet available, in *RowColDesc* add sheet row / column description (in English) and index numbers

4. **Activate** the *Generate* button to update the variable list (*Dataset.bas)*
   Import this file into VBA by following the subsequent steps:
   1. Select the Dataset module in the left pane of the VBA programming environment
   2. Right-click and select *Remove Dataset*
   3. Right-click again, select *Import file* and select the file *Dataset.bas* from the folder where the e3.kz workbook is stored

5. **Add** corresponding **historical data** into the *Values* sheet (if applicable)

6. How is the variable determined in the future?
   1. Exogenous → next step see “Create a Scenario”
   2. Estimation → next step see “Modify regressions”
   3. By definition → next step see “Modify the (VBA) model code”

7. **Press the *Run* button** on the *Model* sheet and finally,

8. **Check** the *Results* sheet for the expected outcome

[How to] Modify regressions

1. **Press the *Export data for regressions* *button*** on the *Values* sheet to generate the *series.csv* file

2. **Open "R" project file** by double-click on *regs.Rproj* in the *regs* directory of the model

3. ***Execute the file allRegs.R*** (Ctrl+Shift+Enter) to *load the data set*

4. **Select** appropriate **regression file**, e. g. *employment.R*
   Modify regressions by
   a) Adjusting the limits (*subset* and *gr*) due to new data
   b) Adjusting the specification of regression equation

5. **Execute the file allRegs.R** (Ctrl+Shift+Enter) to update the *Regression.bas* file including *estimated parameters and regression equations* in (VBA) model code

6. **Import the *Regression.bas* file into VBA** by following the subsequent steps:
   1. Select the *Regressions* module in the left pane of the VBA programming environment
   2. Right-click and select *Remove Regressions*
   3. Right-click again, select *Import file* and select the file *Regressions.bas* from the folder *regs* where the e3.kz workbook is stored

7. **Press the *Run* button** on the *Model* sheet and finally,

8. **Check** the *Results* sheet for the expected outcome

[How to] Modify the (VBA) model code

1. **Open VBA programming environment**
   (Alt+F11)

2. **Double-click on the appropriate module**
   a) Model (economic model)
   b) Energy (module)
   c) Emissions (module)

   and enter your equations

   IMPORTANT: sequence of equations matter!

3. **Press the *Run* button** on the *Model* sheet and finally,

4. **Check** if the new data point is shown in the *Results* sheet

[How to] Create a scenario (or [how to] tweak model variables

1. **Add (or select) the model variable to be tweaked** in the *Scenario* sheet
   IMPORTANT: not each variable / each element is tweakable

2. Add **mandatory information** on the *Scenario* sheet (number of row(s), column(s), tweak type and activate tweak)

3. If appropriate, activate **interpolation**

4. Enter the **values** for the respective years
   IMPORTANT: tweaking is not possible before lastdata
   HINT: some assumptions require auxiliary calculations which should be done in the workbook "*ScenarioInput.xlsx*"

5. If appropriate, (de-)activate **other tweaks**

6. **Press the *Run* button** on the *Model* sheet and finally,

7. **Check** the *Results* sheet for the expected outcome

[How to] Evaluate results of one scenario

1. **Press the *Run* button** on the *Model* sheet

2. After each model execution the **full** (historical and projected) **data set is automatically copied to the** *Results* sheet

3. **Evaluate the results**
   IMPORTANT: results are given as absolute values for one scenario!

   a) Preprepared evaluation tool *"4 Variables"* sheet allows to select up to four variables (add variable name, row and column in the dark grey box)

      → Values can be **displayed** in respective units, annual average growth rates or index values

   b) Model users can create their own views based on the *Results* sheet

[How to] Compare and evaluate results of two scenarios

1. **Open _*Compare2Scenarios_.xlsb*** in the folder *scenarios* (IMPORTANT: allow execution of macros)

2. ***Press the "1. Step: Update List of Scenarios" button*** on the *SelectScenarios* sheet (new update necessary once new scenarios are calculated)

3. **Click in the left box** on the scenario which should serve as **reference** scenario

4. **Click in the right box** on the scenario which should serve as an **alternative** scenario

5. If appropriate, **extend the list with variables** in the *SelectScenarios* sheet which should be evaluated

6. **Press the "2. Step: Read and COMPARE Results" button** (update necessary once new scenarios are selected)

7. **Analyze results**
   IMPORTANT: results are given as differences between the two scenarios for selected model variables!
   a) Preconfigured graphs in grey colored sheets show differences for a single year.
      The respective year must be selected from the red box on the *SelectScenarios* sheet.
   b) Preconfigured graphs in red colored sheets show differences for the years 2022–2050.

1. INTRODUCTION

Climate change poses major challenges for Kazakhstan. The outstanding importance of climate change for Kazakhstan was also stated by the President of the Republic of Kazakhstan Mr. Tokayev at the General Debate of the 75th session of the UN General Assembly: "Kazakhstan is very vulnerable to various effects of climate change" (UNGA 2020). The country is confronted with increasing temperatures, changed precipitation patterns as well as more frequent, more severe and recurring extreme weather events such as droughts and floods.

Climate change not only affects the environment but also causes immense economic costs, affects key industries and endangers jobs, wealth and life of Kazakh people.

Adaptation to climate change aims at limiting the adverse impacts of climate change while maximizing the benefits. Various adaptation options and evaluations exist for certain economic sectors and climate hazards. Usually not well-known are the macroeconomic impacts and intersectoral effects of climate change and adaptation which go beyond single economic sectors analyses.

However, the knowledge of the economy-wide effects of climate change and sectoral adaptation measures in terms of GDP, employment and CO_2 emissions is vital for Kazakhstan to develop climate-resilient economic development strategies. Environmentally extended economic models in combination with scenario analysis support policy-makers with these issues.

The global program "Policy Advice for Climate Resilient Economic Development" (CRED) and the follow-up project (CRED II) support respective ministries in Kazakhstan as well as in Georgia and Vietnam in developing climate-sensitive development plans and economic development strategies by:

(1) Developing methods and tools for modelling the economic impacts of climate change

(2) Capacity building through training and coaching: Supporting the lead executing agencies and implementing partners to become independent users of the macro-economic models

(3) Supporting the lead executing agencies and relevant stakeholders in integrating the results in policy-making processes and adaptation planning (planned products and activities of policy advice support)

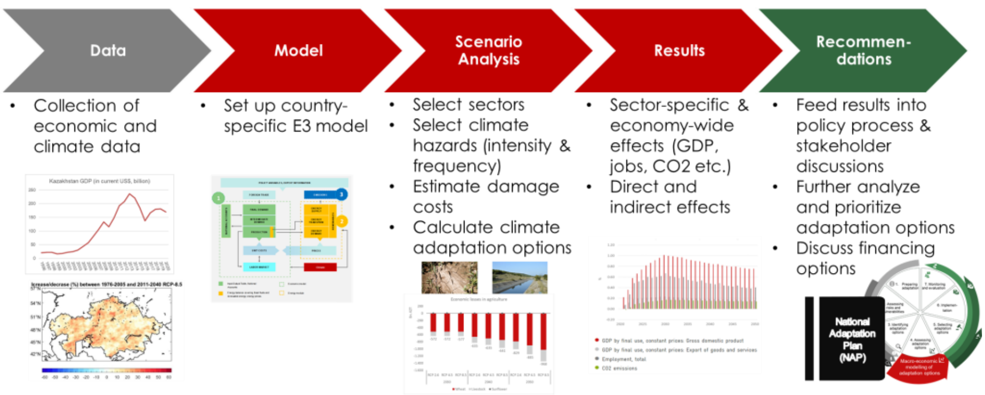

Figure 1: CRED Process: Macro-economic modelling for evidence-based policy making

Source: GIZ

Figure 1 shows the CRED process under which the modeling activities are conducted. The process started with the compilation of economic and climate data, followed by the development of the e3.kz model which was then applied to climate change and adaptation scenarios. The macroeconomic results are then fed into stakeholder discussions and policy processes (Dekens and Hammill 2021, GIZ 2025b) to support evidence-based adaptation solutions.

This process is supported by an extensive exchange with Kazakh partners, experts and the cooperation between the Ministry of National Economy (MNE) of the Republic of Kazakhstan, the Institute of Economic Research (ERI), GWS and GIZ and resulted in the **development and application of the e3.kz[1] macro-econometric model for Kazakhstan**.

From 11/2023 to 03/2024, the existing E3 models in Georgia and Kazakhstan were extended, updated and applied to updated climate change scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) as well as adaptation measures based on more detailed cost-benefit analyses. This process was supported by national and international experts, e.g. ERI, AvantGarde Group, Berlin Economics and Earthyield Advisories.

The e3.kz model supports in understanding and quantifying the macroeconomic impacts of climate change and adaptation measures by conducting scenario analysis. Climate change and adaptation scenarios were designed comprising information and data on the most relevant climate hazards, their sector-specific impacts as well as suitable adaptation options.

The e3.kz model results do not only show the direct effects but also the indirect and induced macroeconomic consequences (GDP, imports, sector-specific production and employment) for Kazakhstan due to economic interrelationships. Model results of the climate change scenario show **what could happen under climate change** (awareness raising under uncertainty). Model results of the adaptation scenarios **support policymakers to identify those adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment** (win-win options). However, although the financial and economic impacts are relevant for policymakers to decide which adaptation measure is "most effective", other criteria – which are beyond the scope of the model – must be considered as well such as health aspects and ecosystem services (biodiversity, regulation of the water balance) to get a more comprehensive evaluation and to formulate an appropriate adaptation strategy.

Under the CRED I and II program, Kazakh model builders and model users were trained (in particular ERI) for whom this updated model handbook serves as reference material for future trainings and future application of the model. Supplementary material is provided in PowerPoint format and recorded videos which were presented during the trainings and coaching sessions. Furthermore, condensed tutorial videos were created:

1. General introduction to the DIOM-X model building framework
2. How to tweak model variables?
3. How to perform scenario analysis?
4. How to evaluate results of one scenario?
5. How to compare and evaluate results of two scenarios?
6. How to update the historical database?
7. How to extend the model database?

[1] E3 models contain three interlinked model parts, consisting of an economy model (1) enhanced by energy (2) and emission (3) modules. The abbreviation kz indicates Kazakhstan for which the model is built.

8. How to modify regressions?
9. How to edit the (VBA) model code?

The first five videos are relevant for the model users and model builders. The videos number six to nine are in particular relevant for model builders.

1.1 E3.kz – A tool for modeling the economic impacts of climate change and adaptation in Kazakhstan

For an economic model to be climate change aware, it needs to capture the economic impacts directly caused by climate change (and adaptation) but also has to consider supply chains. Furthermore, such an economic model must quantify long-term economic developments (until 2050) to be able to show future impacts of climate change as well.

In principle, three basic types of macroeconomic models can be distinguished according to the underlying philosophy and understanding of the interaction of an economy: Computable General Equilibrium models (CGE), static Input-Output (IO) models and macro-econometric (or dynamic) Input-Output models, according to Máñez et al. 2016). A combination of climate and economic models results in Integrated Assessment Models (IAM) and Disaster Impact Models (DIM) (see Lehr et al. 2020).

For Kazakhstan, the macro-econometric (dynamic) IO modeling approach in combination with scenario analysis is suitable to study the economy-wide impacts of climate change and adaptation[2]. In contrast to static models – which compare a situation before and after a change (comparative static analysis) – the proposed dynamic IO model is time-dependent and considers the economic development and transition processes.

International experiences as well as GWS experiences with similar projects – for example SOCLIMPACT[3] and ToPDad[4] show that this approach fulfills the necessary requirements and can be successfully implemented (Aaheim et al. 2015, Lehr et al. 2016, 2018, 2020).

Furthermore, IO models already exist at the implementing partner institution ERI, so that this experience can be built upon. As Kazakhstan is in the process of transition to a “green economy”, the dynamic IO model was extended to an E3 (economy, energy, emission) model, so that it is also possible to identify synergies and trade-offs of adaptation and mitigation strategies as well as Nationally Determined Contribution goals.

This modeling approach, key requirements and necessary data have been jointly discussed and selected during on-site and remote meetings in 2020 with various Kazakh partners and experts (amongst others ERI, Zhasyl Damu, TALAP, Committee of Statistics).

The requirements for data and the model approach are kept moderate for a sustainable solution which is also important for the model ownership. However, the model approach is flexible, can be expanded in many ways and allows for integrating expert input.

[2] For a detailed representation of these impacts please refer to Großmann et al. 2021.
[3] https://soclimpact.net/
[4] http://www.topdad.eu/

The e3.kz model is fully developed in Microsoft (MS) Excel using the model building framework DIOM-X. The framework is built upon the Excel built-in programming language Visual Basic for Applications (VBA) and was developed for creating **D**ynamic **I**nput-**O**utput **M**odels in E**x**cel (Großmann and Hohmann 2019). The DIOM-X model framework code and its documentation are preexisting work of GWS. It is distributed with royalty-free, non-exclusive rights only to project partners and training participants. It may be used to operate, maintain, and extend the e3.kz model but not to develop similar and / or commercial products ("fair use").

The full model database, model equations, scenario settings and results are stored in a single Excel workbook to ensure that all aspects of the model can be examined, adjusted and extended (Figure 2, in parenthesis respective manual sections are indicated).

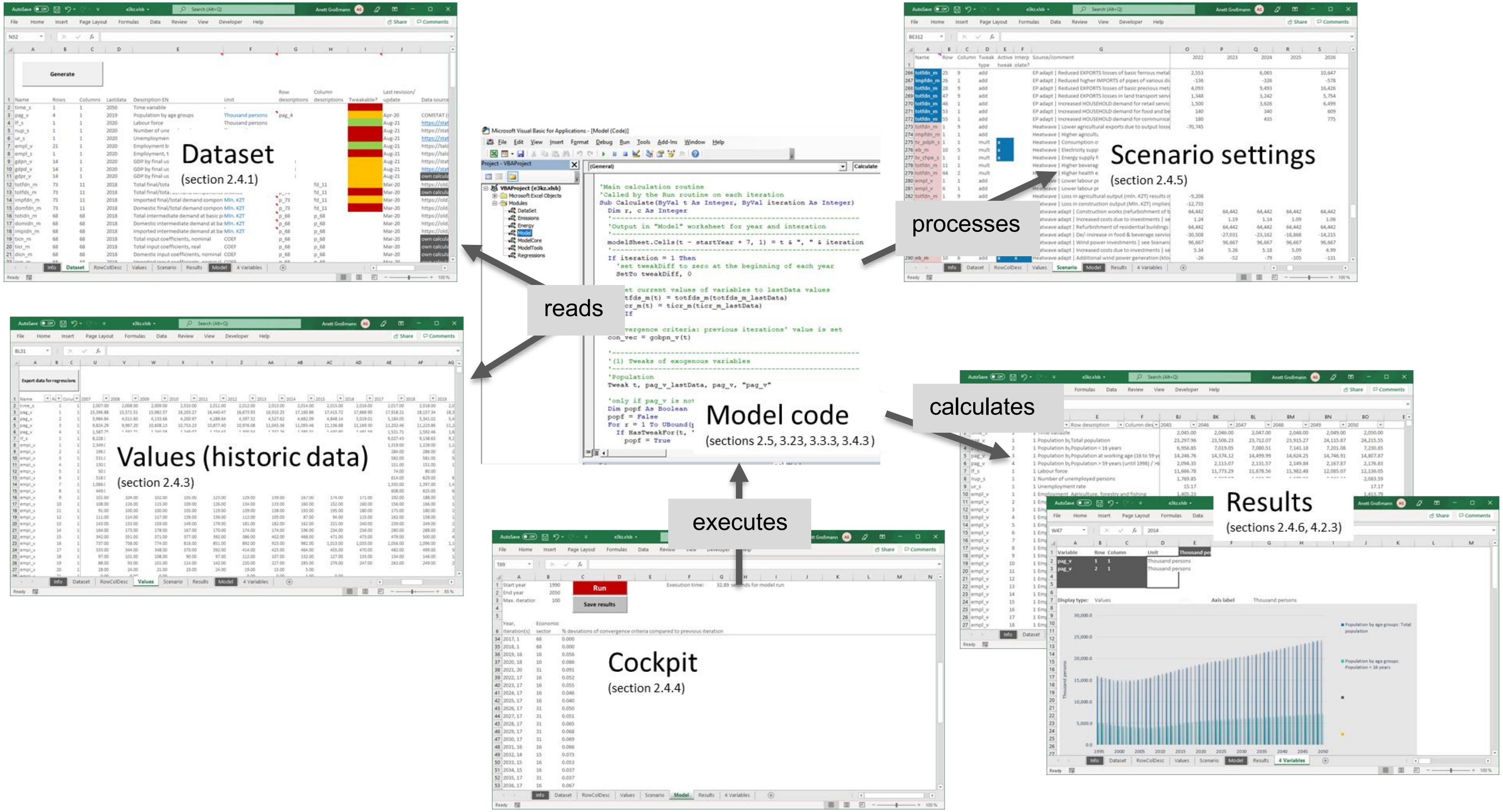

Figure 2: Overview of the E3.kz model in MS Excel

Source: Own illustration

1.2 Structure of the e3.kz model handbook

This manual provides a detailed description of the e3.kz model. In particular, it serves as a guide for model builders and model users, and is aimed to support the active work with the e3.kz model.

Chapter 2 gives a detailed, technical description of the model. In section 2.2 the main model building steps are introduced on which the structure and design of the DIOM-X model building framework is built upon (section 2.3). The Microsoft (MS) Excel file that contains the e3.kz model is described with all its different worksheets and functionalities (section 2.4), the VBA programming environment (section 2.5) and modules (section 2.6). Besides Microsoft Excel, "R" is used to perform regression analysis. Section 2.7 provides information on the linkages between MS Excel and "R" and how the exchange of data and regression equations works.

Chapter 3 provides a description of the three interlinked model parts (economy, energy, emission). First, a general overview of the model building approach of the e3.kz model for Kazakhstan is presented (section 3). In the subsequent sections 3.2 - 3.5, all three model parts are explained by giving a general overview on the modelling approach, the data sets used and the implementation of each part into DIOM-X.

In the last chapter 4, an introduction to scenario analysis with e3.kz is given. The purpose of "what-if"-analyses, data requirements and the procedure on how to implement climate change adaptation scenarios into e3.kz is described.

The manual is accompanied by the Excel file *e3kz.xlsb* including the model framework code, the full data set, all model equations including regressions and model results. The model e3.kz is a result of the cooperation between the GWS consultants Anett Großmann, Frank Hohmann and the Economic Research Institute (ERI, Astana, Kazakhstan).

We would also like to thank the local GIZ staff Dana Yermolyonok and Alvira Yertayeva as well as the translators Igor Bauer and Madina Kamasheva, who were continuously supporting the capacity building process.

If you have any questions and/or comments please contact us via email:

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hohmann@gws-os.com (model building framework DIOM-X)

2. DIOM-X MODEL BUILDING FRAMEWORK

2.1 Overview

Today, hundreds of programming languages exist and each of them has been developed to overcome some problems or to improve certain features of other languages. In principal, almost any of these programming languages may be used to build an environmentally enhanced economic model (E3 model), although each of them has its strengths and weaknesses.

MS Excel as a typical spreadsheet program is usually applied for static analytical problems by depicting relations between variables via links between spreadsheet cells. For an elaborated E3 model, this approach is not suitable because the various interdependencies cannot be efficiently expressed via cell linkages. Thus, the model building framework DIOM-X is based on the VBA programming language instead. The core of an E3 model is a set of equations which describe the various model inter-dependencies. The number of variables and equations does not allow for an explicit solution of the equations system but requires an iterative solution algorithm.

Most users of MS Excel neither know nor require the programming language VBA which is part of the MS Office suite of applications. The use of MS Excel as a foundation for IO modelling is appealing because:

- MS Excel is already installed on most professionally-used computers
- Most statistics are available in MS Excel format
- Existing knowledge about data processing in MS Excel can be reused
- Data (historical, projected) and model code can be stored and distributed as a single unit (= workbook)
- The VBA programming is sufficiently fast to solve equation systems of moderately-sized E3 models (from 10 sec up to 1 min per simulation)

A model by definition is always a simplification of a (real world) counterpart. Thus, an E3 model depicts the relevant relations within an economy and between the other E3 model parts but omits detail that is not necessary for the main topic the model tries to address. In order to apply and interpret such a model properly, model builders and model users need to be aware of the set of assumptions and model simplifications. Some models are facing the allegation being a "black-box" due to the fact that underlying data, model assumptions and equations are not fully visible to other modelers. The approach applied solves that issue. It stores the full data set, framework and model code in a single workbook ensures that all aspects of the model can be examined, verified and – if necessary – extended ("white-box" approach).

The framework supports an iterative model building process that encompasses four main steps (section 2.2). The core framework architecture is briefly described in section 2.3. A set of worksheets (section 2.4) represent the visual components of the mod-el. They establish the interaction between users and the model (data set maintenance, scenario definition, model execution, etc.). section 2.6 discusses the main features of the VBA programming environment. The model code containing both the framework and the equation system is organized in separate programming units called modules (section 2.7) which are embedded in the aforementioned VBA programming environment.

MS Excel as a spreadsheet application offers limited functionality with regard to regression analysis. Section 2.7 shows how to perform regression analysis with "R" and the procedure to include the resulting regression equations and coefficients into VBA.

2.2 Model building steps

Although E3 models greatly differ with respect to their research focus and detail, they share the same basic development cycle:

1. Database management
2. Regression analysis
3. Model implementation
4. Scenario analysis

(1) Database management: The foundation of every quantitative model is data collect-ed from different sources which needs to be harmonized before it can be processed by the model. This involves i. e. assigning variable names and meta information (e. g. unit) as well as harmonizing the layout of the values (e. g. years in columns). DIOM-X provides the necessary template sheets (section 2.4) and data processing routines.

(2) Regression analysis: The availability of historical data is the most important prerequisite for regression analysis which is carried out by econometric models to estimate model parameters for behavioral equations. Instead of using elasticities from the literature, relationships of variables known from e. g. economic theory are econometrically tested against historical data. MS Excel's capabilities are rather limited compared to more specialized software such as EViews or "R". In order to easily share historical data, DIOM-X provides an data export routine for the most popular econometric and statistical software packages (see Sections 2.4.3 and 2.7).

(3) Model implementation: The main task of this model building step is to create the model structure by putting the set of equations together. Most equations – both regressions and definitions – are not independent but interrelated. Left-hand-side (LHS) variables of one statement occur as right-hand-side (RHS) variables in another equation. One of the biggest problems in this stage is that at the beginning many variables which occur as RHS variables in some equation have not yet been specified. Thus, a lot of mathematical problems occur, e. g. division by zero. To minimize such problems, the DIOM-X framework keeps the values of variables constant in the future unless a specification is given. The framework also helps protect historical data from being overwritten accidently by evaluation of the *lastdata* property that indicates the last historical year for which data is available. The integrated debugging tools of the VBA programming environment further help to track down problems through runtime-inspection and step-by-step execution.

(4) Scenario analysis: DIOM-X provides a simple to use mechanism for performing scenario analysis. Model users can specify sets of quantified assumptions which will be automatically injected into the model at runtime. The assumptions can vary with respect to time frames, values and type (e. g. growth rate or value replacement). Once the scenario calculation is finished, the framework automatically copies the full data set (both historic and projected) to the *Results* worksheet for further inspection (section 2.4.6).

The more complex the model, the more unlikely it is that these steps can be performed in strict sequence. With most models, these steps are carried out iteratively for various reasons – mostly, because in a certain step missing information or errors are detected which induces another loop.

DIOM-X actively supports this iterative approach by logically separating the different kinds of information.

2.3 Model framework

Although quantitative models greatly differ in detail and their underlying data sets, they share – from a technical point of view – many properties: Data needs to be read in, as-signed to variables, assumptions need to be fed into the model, an equation system must be repeatedly solved until a certain convergence criterion is fulfilled, results need to be stored, etc. The DIOM-X modeling framework captures these similarities in an easy to use, model-independent framework built upon a set of visual and non-visual components.

The visual components are dedicated to the interaction with both model builders and model users, i. e. database maintenance, model execution, scenario definition and visualization of model results. The related information is provided via a set of worksheets which are described in the next section 2.4. The visual components do not require any programming skills, thus model users with average knowledge in the handling of the MS Excel application are able to compute and evaluate scenarios as well as maintain the dataset. The interpretation of the results requires model users to be familiar with the core building blocks of the model.

The non-visual components are related to the programming part of the model. The framework provides automated, model-independent procedures to perform scenario analysis as well as a set of helper functions not found in MS Excel to simplify the formulation of the equation system (i. e. matrix algebra). The model framework code is separated from the model code. These separated program units are called modules (see section 2.6).

The MS Excel workbook serves as a container for both the visual and non-visual com-ponents which ensures that all relevant information is available any time in its most re-cent version.

2.4 MS Excel sheets

2.4.1 Dataset

The core of any quantitative model is the data set which is compiled from a number of model variables. The DIOM-X framework provides the *Dataset* worksheet as a template to collect and maintain the set of variables (Figure 3).

Each variable is described by a set of properties. Some of these properties are essential for model operation (core properties, e. g. variable name). Additional properties contain meta-information which is not used by the underlying model code but help understanding and maintaining the data set.

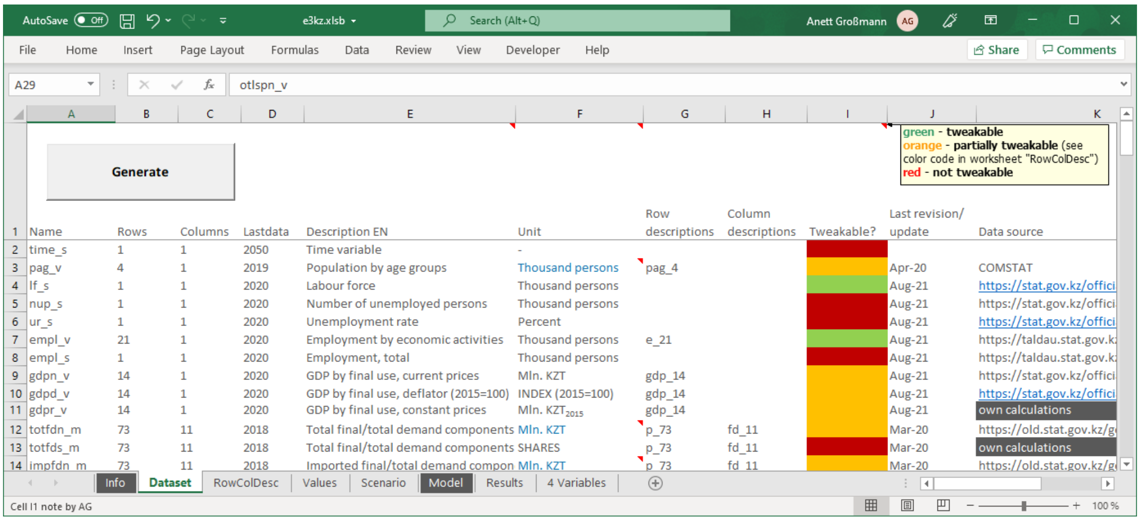


Figure 3: Dataset worksheet

Source: Own illustration.

The four core properties of a model variable are the following:

Name: Each model variable must be uniquely named. The name is used to address the variable in the model code (i. e. assigning data, performing calculations). With hundreds, sometimes thousands of variable names, identifying each of them becomes difficult without a proper naming convention based on a set of rules. The following rules present a guideline for a naming convention:

- use lower case characters for variable names only
- take the first character of every (English) noun / important word describing the variable, e. g. total final demand components at basic prices: *tfdbp*. If there are only one or two words, try to use four characters for the name, e. g. Employment: *empl*
- append one character indicating the price concept or shares (if applicable):

  n nominal values, e. g. tfdbp*n*
  d deflator
  r real
  s shares, e. g. tfdbp*s*

- add a suffix indicating the variable type (see the next properties *Rows* and *Columns* for details):

_v vector, e. g. empl_*v*
_m matrix, e. g. eb_*m*
_s scalar, e. g. lf_s

Rows / Columns: The framework distinguishes three types of time series. A simple time series has one value per year (e. g. labor force). For information available for economic activities, the framework allows for combining such information into one variable which stores more than one value per year (e. g. employment by economic activities).

A simple time series with one value per year has only one row and one column. If a variable contains sector information, these values are usually stored in multiple *rows* (*vector*), thus the value of the property *Rows* is greater than one and the value of *Columns* is equal to one (e. g. employment by economic activities).

For variables which contain information describing certain relations (e. g. energy balance, IO table) both the number of *rows* and *columns* are greater than one (*matrix*).

In the model code, elements of multidimensional variables are addressed via indices given as integer values.

This approach not only greatly reduces the number of variables but also simplifies the programming of the equation system. The framework contains a set of routines to per-form vector / matrix algebra that help to streamline the model code (see Appendix 1 for the list of routines).

Lastdata: The data of a quantitative model contains both historical and projected data. The *lastdata* property describes the last year for which historical data is available. This information is used by the framework to protect historical data from being (accidently) overwritten.

The other columns in the *Dataset* worksheet contain meta information which help to further describe a variable. Model builders might be tempted not to properly fill in this information as it is not used by the calculation engine. Considering that often more than one person is engaged into the model building process and that a model usually needs to be maintained for several years, model builders are strongly advised to provide the following additional information for each variable:

Description: This property contains a short description of a variable. The user can select in cell E1 between EN – English and KZ – Kazakh. A prerequisite for switching languages is that all variable names, their English and Kazakh description are given in the (hidden) worksheet *Translation*. After executing the *Run* button, the *Results* worksheet shows the selected language.

Unit: This property describes the unit of the data. Such information is especially useful for defining / verifying unit conversions in the model code.

Row / Column Description: These columns contain the names of row and column de-scription lists for variables that store more than one value per year (*vectors* and *matrices*). Details are stored in the *RowColDesc* worksheet (see next section).

Last revision: This property should be used to indicate when a variable the last time has been checked for updates. This information is essential for model maintenance.

Data Source: This property indicates the provider of the data for a certain variable which could either be some external data source or the model itself if the values are calculated internally.

The *Generate* button connects the data set to the model code (for details refer to section 2.6.1).

2.4.2 RowColDesc

This worksheet (Figure 4) contains descriptions for multidimensional model variables (time series of *vectors* and *matrices*).

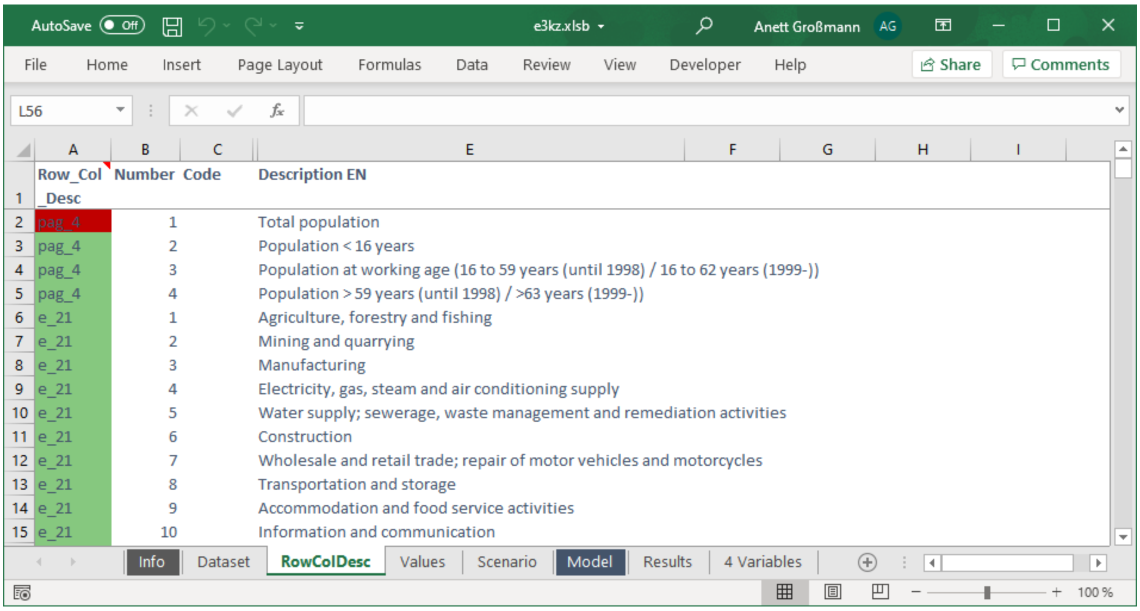


Figure 4: RowColDesc worksheet

Source: Own illustration.

Row_Col_Desc: This column contains the name of a list/group of components. As mentioned before, this name is used as a reference in the *Dataset* worksheet (see previous section).

Number: This value serves as an index for the different rows (and columns) of a multi-dimensional variable.

Code: If a statistical item code is available, it may be entered here, e. g. SNA item code.

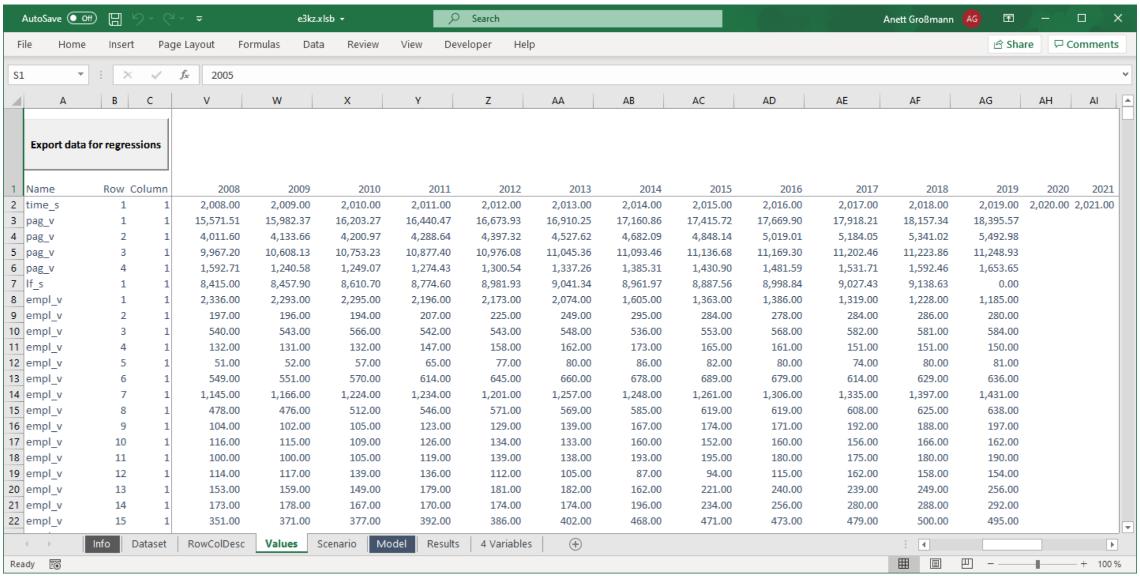
Description: This property contains a description of the element. Column E contains the English description and the (hidden) column D the Kazakh translation. After executing the *Run* button, the *Results* worksheet shows the selected language.

The framework uses this information to annotate the model results in the *Results* work-sheet (see section 2.4.6). Thus, model builders and users do not have to remember the variable names and elements of multidimensional variables. Furthermore, creating customized subsets of the data set (dashboards) becomes much easier with all necessary information combined within a single worksheet.

2.4.3 Values

The *Values* worksheet contains the historical data that is associated to the variables of the data set (Figure 5). All data that needs to be processed by the model must be part of this worksheet. The data can be incorporated in different ways, depending on the structure of the original data sources as well as the data processing skills of the model builder:

- Copy & paste
- Linking of cells to the original data sources (stored in the *data* folder, cf. section 3)
- Import via automated data pre-processing tasks in VBA or other programming languages



Name	Row	Column	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
time_s	1	1	2,008.00	2,009.00	2,010.00	2,011.00	2,012.00	2,013.00	2,014.00	2,015.00	2,016.00	2,017.00	2,018.00	2,019.00	2,020.00	2,021.00
pag_v	1	1	15,571.51	15,982.37	16,203.27	16,440.47	16,673.93	16,910.25	17,160.86	17,415.72	17,669.90	17,918.21	18,157.34	18,395.57		
pag_v	2	1	4,011.60	4,133.66	4,200.97	4,288.64	4,397.32	4,527.62	4,682.09	4,848.14	5,019.01	5,184.05	5,341.02	5,492.98		
pag_v	3	1	9,967.20	10,608.13	10,753.23	10,877.40	10,976.08	11,045.36	11,093.46	11,136.68	11,169.30	11,202.46	11,223.86	11,248.93		
pag_v	4	1	1,592.71	1,240.58	1,249.07	1,274.43	1,300.54	1,337.26	1,385.31	1,430.90	1,481.59	1,531.71	1,592.46	1,653.65		
lf_s	1	1	8,415.00	8,457.90	8,610.70	8,774.60	8,981.93	9,041.34	8,961.97	8,887.56	8,998.84	9,027.43	9,138.63	0.00		
empl_v	1	1	2,336.00	2,293.00	2,295.00	2,196.00	2,173.00	2,074.00	1,605.00	1,363.00	1,386.00	1,319.00	1,228.00	1,185.00		
empl_v	2	1	197.00	196.00	194.00	207.00	225.00	249.00	295.00	284.00	278.00	284.00	286.00	280.00		
empl_v	3	1	540.00	543.00	566.00	542.00	543.00	548.00	536.00	553.00	568.00	582.00	581.00	584.00		
empl_v	4	1	132.00	131.00	132.00	147.00	158.00	162.00	173.00	165.00	161.00	151.00	151.00	150.00		
empl_v	5	1	51.00	52.00	57.00	65.00	77.00	80.00	86.00	82.00	80.00	74.00	80.00	81.00		
empl_v	6	1	549.00	551.00	570.00	614.00	645.00	660.00	678.00	689.00	679.00	614.00	629.00	636.00		
empl_v	7	1	1,145.00	1,166.00	1,224.00	1,234.00	1,201.00	1,257.00	1,248.00	1,261.00	1,306.00	1,335.00	1,397.00	1,431.00		
empl_v	8	1	478.00	476.00	512.00	546.00	571.00	569.00	585.00	619.00	619.00	608.00	625.00	638.00		
empl_v	9	1	104.00	102.00	105.00	123.00	129.00	139.00	167.00	174.00	171.00	192.00	188.00	197.00		
empl_v	10	1	116.00	115.00	109.00	126.00	134.00	133.00	160.00	152.00	160.00	156.00	166.00	162.00		
empl_v	11	1	100.00	100.00	105.00	119.00	139.00	138.00	193.00	195.00	180.00	175.00	180.00	190.00		
empl_v	12	1	114.00	117.00	139.00	136.00	112.00	105.00	87.00	94.00	115.00	162.00	158.00	154.00		
empl_v	13	1	153.00	159.00	149.00	179.00	181.00	182.00	162.00	221.00	240.00	239.00	249.00	256.00		
empl_v	14	1	173.00	178.00	167.00	170.00	174.00	174.00	196.00	234.00	256.00	280.00	288.00	292.00		
empl_v	15	1	351.00	371.00	377.00	392.00	386.00	402.00	468.00	471.00	473.00	479.00	500.00	495.00		

Figure 5: Values worksheet

Source: Own illustration.

The structure of the data is the same for simple time series as well as for time series of vectors and matrices. In column one *Name*, the variable name is required. In the following two columns, the *Row* and *Column* indices must be specified. In the remaining columns, the values for the respective years must be given. The model framework automatically reads the full data set at the beginning of a simulation and assigns the data to the respective variables.

The historical data is the main prerequisite for step 2: *regression analysis* of the model building process. MS Excel's capabilities to perform regression analysis are rather limited. Thus, the framework on request exports the historical data by pressing the *Export data for regressions* button in CSV format with variable names in columns and years in rows. This special format can not only be imported by "R" but by most other statistical software packages. For details on regression analysis with "R", please refer to section 2.7.

Variables that are endogenously calculated by the model do not have to appear in the *Values* worksheet.

2.4.4 Model

This worksheet is dedicated to the operation of the model (Figure 6). Execution of the model is initiated by pressing the *Run* button which then reads in the historical data, processes the scenario parameters as given in worksheet *Scenario* (see section 2.4.5 and chapter 4), and solves the underlying equation system for the given time span. Details about the algorithm which controls the model execution are presented in section 2.6 which is dedicated to model programming.

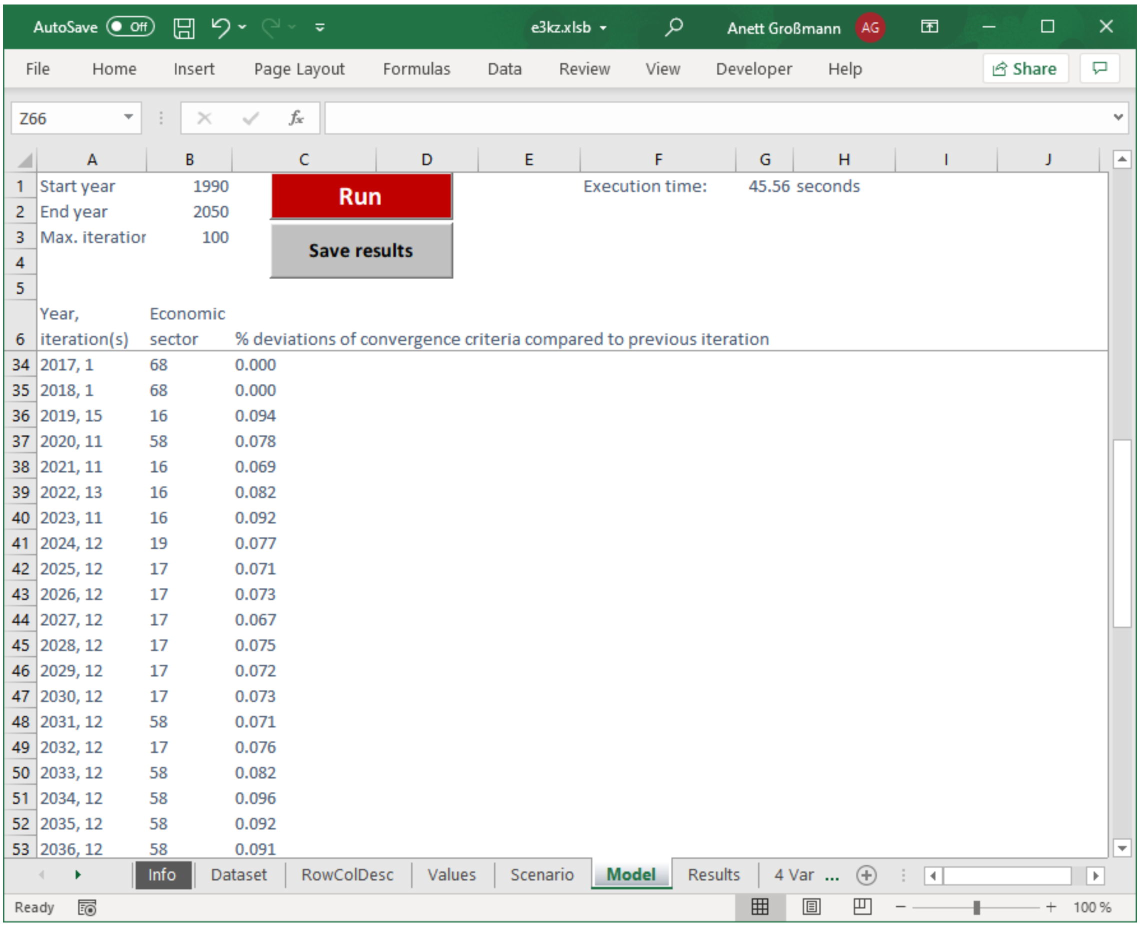


Figure 6: Model worksheet

Source: Own illustration.

Execution of the model can be fine-tuned by adjusting the start and end year as well as the maximum number of iterations per year. Changing the time span of the simulation should only be done by experienced model builders after testing model stability for different time spans.

In cases when the model does not successfully converge, raising the number of maxi-mum iterations per year might help to solve the convergence issue. A correctly specified model in most cases should converge with less than twenty iterations per year, though. Higher numbers usually indicate that the model implementation should be checked for unresolved issues.

At model runtime, starting in cell B7 the economic sector with the greatest difference is shown (or the last element of the vector *gobpn_v* used as convergence criteria) compared to the previous iteration for the respective year (cf. Figure 6). In case of convergence issues, it may help to check first that sector to find the reasons for instability.

Model users should be aware that the results are overwritten each time the model is executed. The results of the most recent model run can be stored separately by pressing the *Save results* button (Figure 6).

2.4.5 Scenario

In the *Scenario* worksheet, model users define assumptions the model has to consider at model runtime. An assumption is defined as one or more numerical value(s) which depict a certain policy, measure or event (e. g. a natural disaster). It may cover a certain time range, may occur just once or repeatedly. A scenario is a combination of one or more assumptions. Defining, applying and comparing scenarios is the main application of an E3 model based on DIOM-X and does not require any programming skills.

The DIOM-X model building framework provides four different types of adjustments (*tweaks*) which can be used to build simple as well as complex scenarios:

Table 1: Tweak types

Tweak type	Functioning of the tweak	Example
Gr	The last value is projected with the given annual average growth rate in %.	Last model value in t: 100, gr-tweak in t+1: 3 → result in t+1: 103
add	The given value is added to the value calculated by the model.	Model value: 100, add-tweak: 30 → result: 130
mult	The calculated value is multiplied by the given factor.	Model value: 100, mult-tweak: 1.5 → result: 150
repl	The calculated value is replaced by the given value.	Model value: 100, repl-tweak: 110 → result: 110

Source: Own illustration.

The tweaks may be applied to simple time series as well as elements of time series of vectors and matrices (Figure 7).

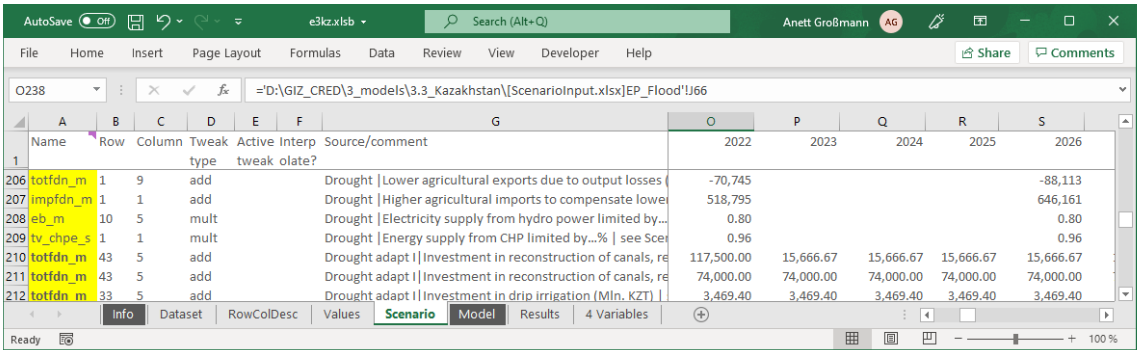


Figure 7: Scenario worksheet

Source: Own illustration.

The necessary information to apply a tweak to a certain variable must be given as follows:

Name: The name of the variable to be tweaked. It must already be part of the data set.

Row and **Column**: The row and column indices of the element which is tweaked. If a simple time series is tweaked, both indices must be 1.

Tweak type: The name of one of the four tweak types as listed in Table 1.

Active tweak: Indicates whether the tweak is active (x) or not (blank). This setting helps to formulate and experiment with complex scenarios by trying different combinations of tweaks.

Interpolate: If this setting is activated (x), the framework automatically interpolates the values between two non-consecutive years. This greatly reduces the amount of numbers that need to be typed in.

The remaining columns contain the years with the respective tweak values.

If necessary, a combination of different tweaks may be applied to a single variable. For example, a growth rate could be applied for a certain time span which is then followed by a *replace* tweak for following years.

The content of the *Scenario* worksheet is automatically processed by the framework at model runtime: If a tweak is defined for a certain variable, the given value(s) adjust(s) or replace(s) the values which were calculated by the model.

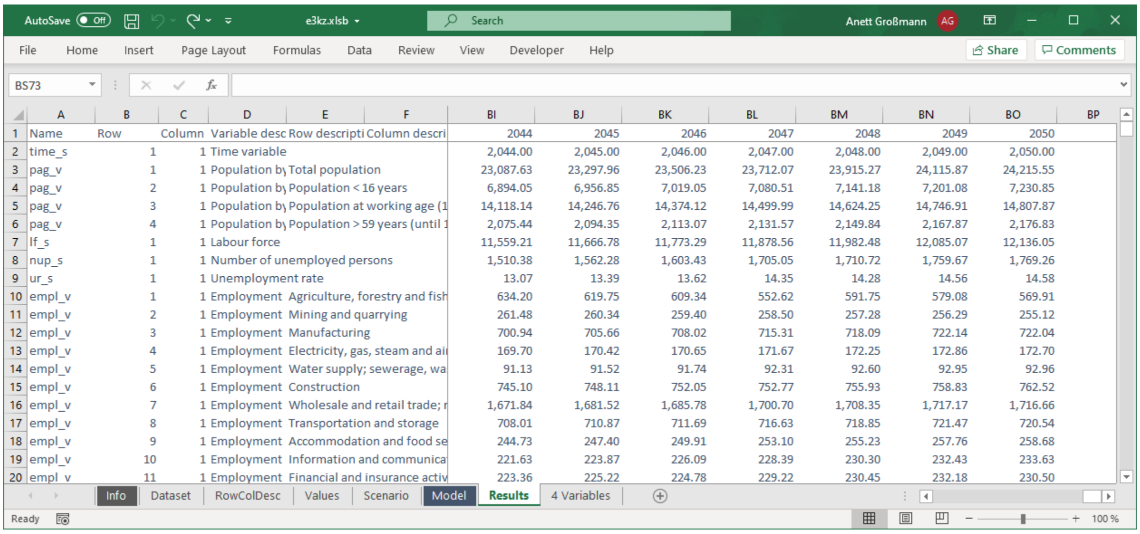
Model builders and model users should be aware of the fact that – due to the high degree of interdependency in the equation system – the full set of effects of a certain tweak is not always obvious. Therefore, it is strongly advised to test and analyze assumptions separately and build more complex combinations of assumptions later. Furthermore, it must be pointed out that unplausible assumptions usually yield unplausible results as the model is not able to verify the plausibility of any assumption.

Moreover, model users should be aware that not all variables of the data set can be tweaked. The color codes set in the worksheets *Dataset* (section 2.4.1) and *RowColDesc* (section 2.4.2) indicate if a model variable is tweakable (green), party tweakable (orange) or not tweakable (red, see also section 4). The model code must contain anchors for tweakable variables which need to be defined by the model builder (see section 2.6.3). Tweaks that do not have these anchors in the model code are simply ignored and thus have no effect or impact. In principal, only exogenous variables or variables which are determined via behavioral equations should be tweakable.

The practical use of the tweaking mechanism for scenario building is discussed in detail in chapter 4 *Scenario or "what-if" analysis*.

2.4.6 Results

At the end of each model execution, the framework automatically copies the full data set (both historical and projected data) to the *Results* worksheet (Figure 8).



	A	B	C	D	E	F	BI	BJ	BK	BL	BM	BN	BO	BP
1	Name	Row	Column	Variable desc	Row descripti	Column descri	2044	2045	2046	2047	2048	2049	2050	
2	time_s	1	1	Time variable			2,044.00	2,045.00	2,046.00	2,047.00	2,048.00	2,049.00	2,050.00	
3	pag_v	1	1	Population by	Total population		23,087.63	23,297.96	23,506.23	23,712.07	23,915.27	24,115.87	24,215.55	
4	pag_v	2	1	Population by	Population < 16 years		6,894.05	6,956.85	7,019.05	7,080.51	7,141.18	7,201.08	7,230.85	
5	pag_v	3	1	Population by	Population at working age (1		14,118.14	14,246.76	14,374.12	14,499.99	14,624.25	14,746.91	14,807.87	
6	pag_v	4	1	Population by	Population > 59 years (until 1		2,075.44	2,094.35	2,113.07	2,131.57	2,149.84	2,167.87	2,176.83	
7	lf_s	1	1	Labour force			11,559.21	11,666.78	11,773.29	11,878.56	11,982.48	12,085.07	12,136.05	
8	nup_s	1	1	Number of unemployed persons			1,510.38	1,562.28	1,603.43	1,705.05	1,710.72	1,759.67	1,769.26	
9	ur_s	1	1	Unemployment rate			13.07	13.39	13.62	14.35	14.28	14.56	14.58	
10	empl_v	1	1	Employment	Agriculture, forestry and fish		634.20	619.75	609.34	552.62	591.75	579.08	569.91	
11	empl_v	2	1	Employment	Mining and quarrying		261.48	260.34	259.40	258.50	257.28	256.29	255.12	
12	empl_v	3	1	Employment	Manufacturing		700.94	705.66	708.02	715.31	718.09	722.14	722.04	
13	empl_v	4	1	Employment	Electricity, gas, steam and ai		169.70	170.42	170.65	171.67	172.25	172.86	172.70	
14	empl_v	5	1	Employment	Water supply; sewerage, wa		91.13	91.52	91.74	92.31	92.60	92.95	92.96	
15	empl_v	6	1	Employment	Construction		745.10	748.11	752.05	752.77	755.93	758.83	762.52	
16	empl_v	7	1	Employment	Wholesale and retail trade; r		1,671.84	1,681.52	1,685.78	1,700.70	1,708.35	1,717.17	1,716.66	
17	empl_v	8	1	Employment	Transportation and storage		708.01	710.87	711.69	716.63	718.85	721.47	720.54	
18	empl_v	9	1	Employment	Accommodation and food se		244.73	247.40	249.91	253.10	255.23	257.76	258.68	
19	empl_v	10	1	Employment	Information and communica		221.63	223.87	226.09	228.39	230.30	232.43	233.63	
20	empl_v	11	1	Employment	Financial and insurance activ		223.36	225.22	224.78	229.22	230.45	232.18	230.50	

Figure 8: Results worksheet

Source: Own illustration.

The layout of this worksheet basically matches the layout of the *Values* worksheet. In addition, for each variable and its components the row and column descriptions are included.

It is important to keep in mind that this worksheet is automatically overwritten each time the model is executed. The main reason is that with higher numbers of calculated scenarios the size of the workbook as well as processing time for storing/loading would increase dramatically. It is up to the model user to save relevant model results separately by using the *Save results* button on the *Model* worksheet (cf. section 2.4.4).

Model users and model builders use the *Results* worksheet to evaluate scenarios, either by looking at certain variables of one scenario or by comparing variables from different scenarios (see section 4.2.4). By having all data for one scenario in a single worksheet, the application of MS Excel's functionality to create tables and graphs is straight forward and does not require any programming skills or in-depth knowledge of MS Excel. Advanced users may create their own tools for scenario evaluation. An example which deals with scenario comparison is discussed in Chapter 4 as part of the climate change scenario analysis.

2.5 VBA programming environment

The VBA programming environment of the MS Office suite of programs is not used by most regular users. Thus, MS decided not to activate it in the main menu ribbon. Activation can be accomplished by either pressing the key combination **Alt+F11** or by customizing the main menu ribbon via the menu entry **File / Options / Customize** ribbon:

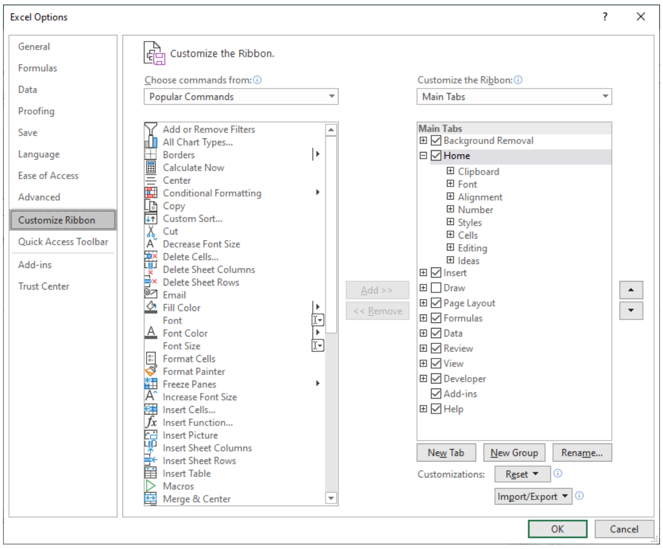


Figure 9: Excel option for developers

Source: Own illustration.

To activate the developer options, the *Developer* entry in the right pane of the dialog needs to be selected (Figure 9). This reveals the hidden developer entries in the main menu ribbon (Figure 10):

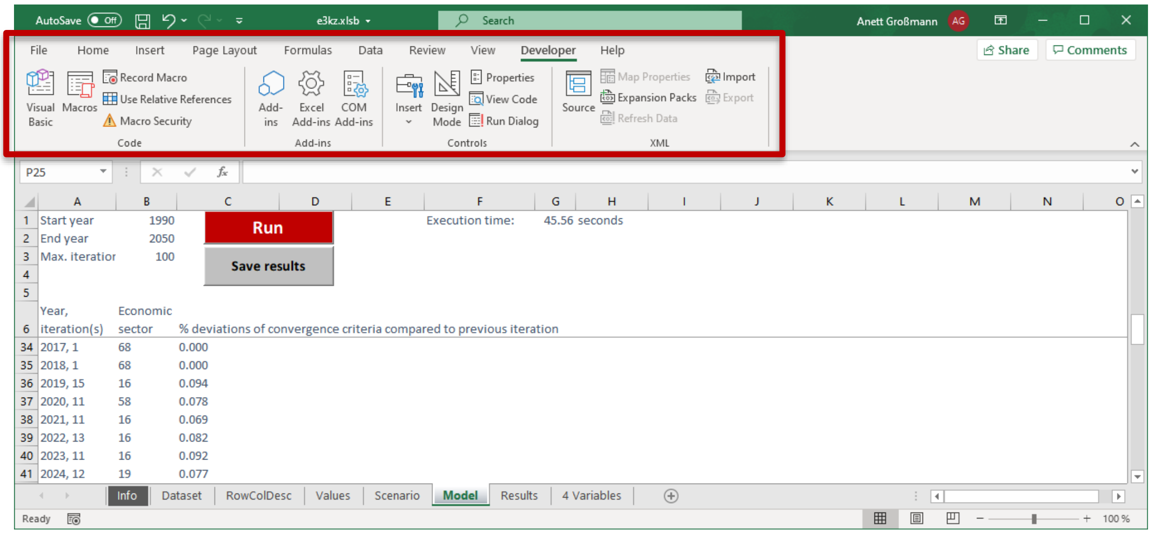


Figure 10: Excel ribbon with activated developer options

Source: Own illustration.

By clicking the *Visual Basic* button, the programming environment is opened. The aforementioned key combination **Alt+F11** has the same effect (Figure 11).

It is out of the scope of this document to explain the programming environment in detail. Model builders not being familiar with VBA should refer to the huge number of internet resources and books that are available in different levels of detail and languages.

One of the most important feature is the integrated debugger which allows for interrupting model execution at any program statement. Once execution is paused, the full data set and other internally used variables (e. g. loop variables) can be examined which greatly helps with tracking down data or programming issues. Model builders should familiarize themselves with the different entries in the *Debug* menu.

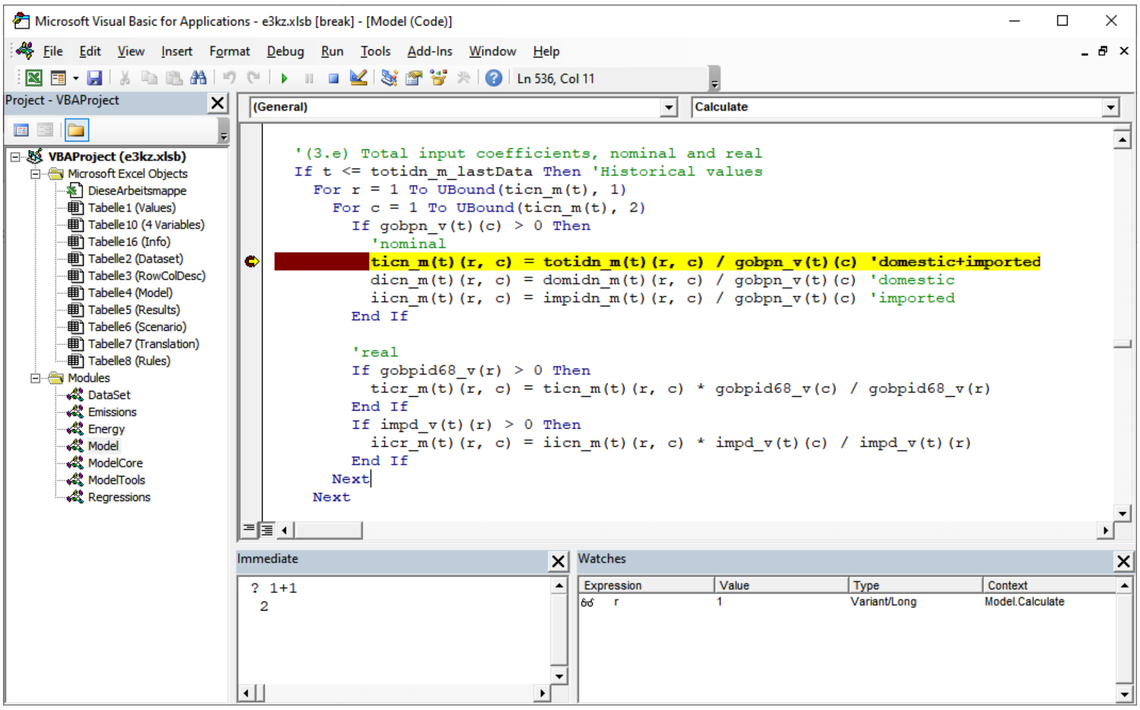


Figure 11: Model debugging

Source: Own illustration.

Another important feature is the concept of separate program units called modules (cf. Figure 9). Program modules allow for

- separating model-specific from model-independent code (the framework)
- dividing the model structure into smaller logical units

and thus greatly improve the structure of a model. Model builders are encouraged to use this feature where appropriate.

The following section discusses the different modules of the DIOM-X model building framework.

2.6 Modules

2.6.1 Dataset

In section 2.4.1, the data set and the different properties of model variables were introduced. The definition of the data set is not sufficient to be able to use the variables in the model code (i. e. the equation system), though. For each of these variables, a variable declaration in VBA syntax is required (Figure 12). To prevent model builders from having to manually perform variable declarations, the *Dataset* worksheet contains the *Generate* button which instructs the framework to generate the full set of variable declarations automatically. The list is saved to a file called *Dataset.bas* in the same directory where the model workbook is stored. For security reasons, Excel does not allow to import this file automatically. This measure ensures that a MS Excel workbook cannot easily create and activate malicious code.

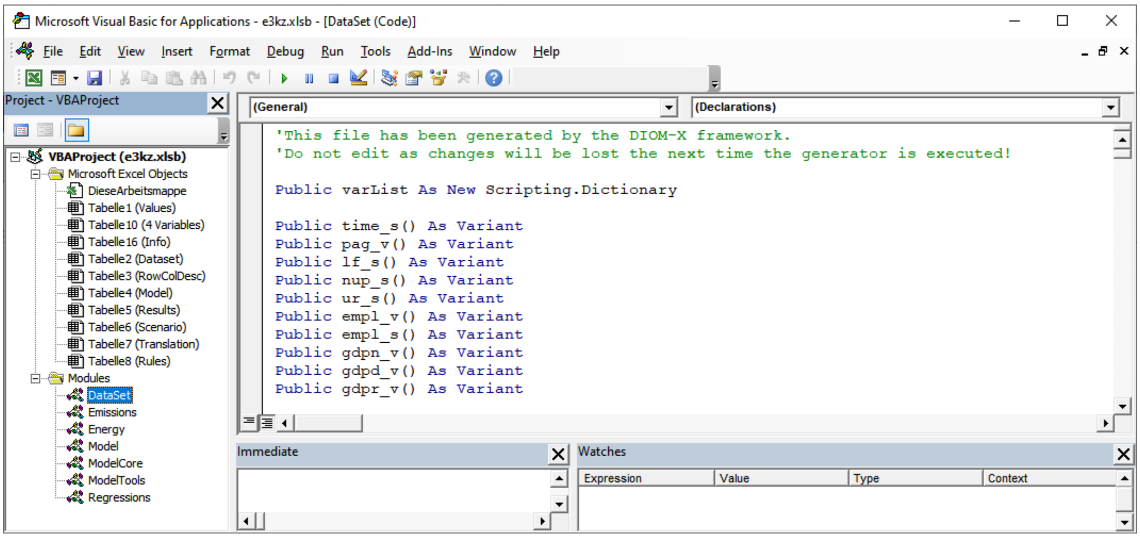


Figure 12: Dataset module

Source: Own illustration.

The necessary steps to import the module containing the variable declarations are as follows:

1. Select the *Dataset* module in the left pane of the VBE programming environment:

2. Right-click and select *Remove Dataset*

3. Right-click again, select *Import file* and import the file *Dataset.bas* from the folder where the work-book is stored.

Unfortunately, Excel does not allow to overwrite an existing module. Therefore, the existing *Dataset* module needs to be removed first.

The framework not only generates the proper variable declarations but also constants for the *Lastdata* prop-erty and specific code to automatically assign the available historical data to the respective variables.

This procedure must be repeated if the data set has changed (e. g. added/removed variables, changes in the number of rows/columns of a variable) to ensure proper mod-el operation.

2.6.2 Model core

The *ModelCore* module contains the model-independent DIOM-X framework code which is used by the model builder "as is" and therefore not discussed in detail.

The most important part of the framework is the processing algorithm which gets executed if the *Run* button is pressed (see section 2.4.4) by the model user. The schematic representation of the algorithm is shown in the following Nassi-Shneiderman diagram (Figure 13):

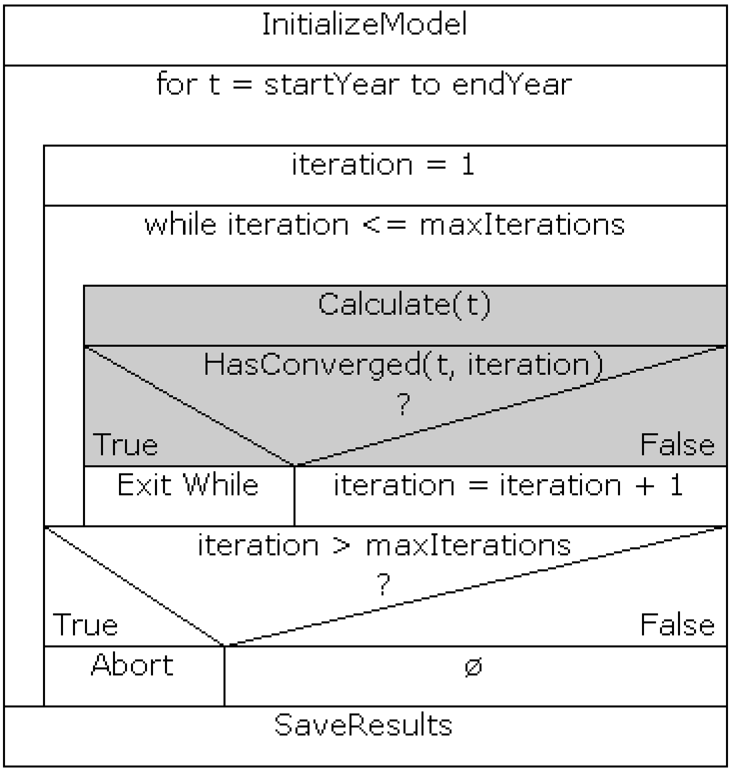


Figure 13: Model processing algorithm (Nassi-Shneiderman diagram)

Source: Own illustration.

As shown in the figure, the algorithm is responsible for the full set of actions that are related to model processing ranging from initializing the model (i. e. reading in and as-signing the historical data) to saving model results to the *Results* worksheet (see section 2.4.6).

An elaborated E3 model consists of a large set of variables and equations which usually needs to be solved in iterations. A typical and widely used approach is to create a huge matrix containing coefficients and apply a solving algorithm such as Gauss-Seidel. The main disadvantage of this approach is that the equations are not explicitly accessible as code statements. This complicates troubleshooting especially in cases where the algorithm fails to successfully solve the equation system.

The DIOM-X framework promotes a different approach: For each year, the algorithm iteratively calls two routines (gray boxes in Figure 13) which need to be provided by the model builder in the *Model* module (see section 2.6.3). The *Calculate* subroutine gets called first and has to provide the full set of model equa-tions. After each iteration, the framework calls the *HasConverged* function. Its return value indicates whether the at-tempt to solve the equation system was successful (return value *true*) or not (return value *false*). If the return value is *false*, the framework initiates another iteration. In some cases, a model cannot converge (i. e. due to missing specifications, data problems). By evaluating the value of the maximum number of iterations as given on the *Model* worksheet (see section 2.4.4), the framework ensures that the model is not caught in an endless loop. If the number of iterations reaches the given upper limit, the model prematurely stops execution and informs the model user that the calculation of the scenario was not successful.

As already pointed out, the equation system usually cannot be solved explicitly. Thus, the model builder has to define a proper convergence criterion in the *HasConverged* function that indicates whether the model successfully converged or not. A common approach is to monitor the value of a certain key variable. If the percentage difference between two consecutive iterations is lower than a given threshold, the *HasConverged* function returns true which instructs the framework to proceed with the calculation for the next year.

Some models need to initialize variables which are not part of the data set (e. g. a unit matrix. In these case, the model builder can use a subroutine *InitializeModel* which is once called by the framework at model start.

Scenario analysis is performed by tweaking the values of certain variables at model runtime. The framework replaces the calculated values of these variables if

- the *Scenario* worksheet contains active tweak entries and
- a corresponding tweak statement is found in the model code as part of the aforementioned *Calculate* routine in the *Model* module (see section 2.6.3).

The tweak statement is defined as

```
Sub Tweak(ByVal t As Integer, ByVal lastData As Integer,
ByRef var As Variant, ByVal varName As String)
```

t: Year to check for the presence of a tweak.

lastData: Last year of available data of the variable.

var: Variable reference

varName: Variable name to apply the tweak for

Example: `Tweak t, lf_s_lastData, lf_s, "lf_s"`

For convenience, the model framework automatically generates a constant for the "last data" value of each variable by appending *_lastData* to the respective variable name.

In addition to routines that are dedicated to proper model operation and scenario specification, the framework provides a set of routines related especially to matrix algebra which are not present in the MS Excel libraries (e. g. matrix multiplication). These routines are listed in the Appendix 1.

2.6.3 Model

The Model module contains the model specifications defined by the model builder. As already discussed in the previous section 2.6.2, model builders have to provide two subroutines *Calculate* and *HasConverged* to ensure proper model operation (Figure 14).

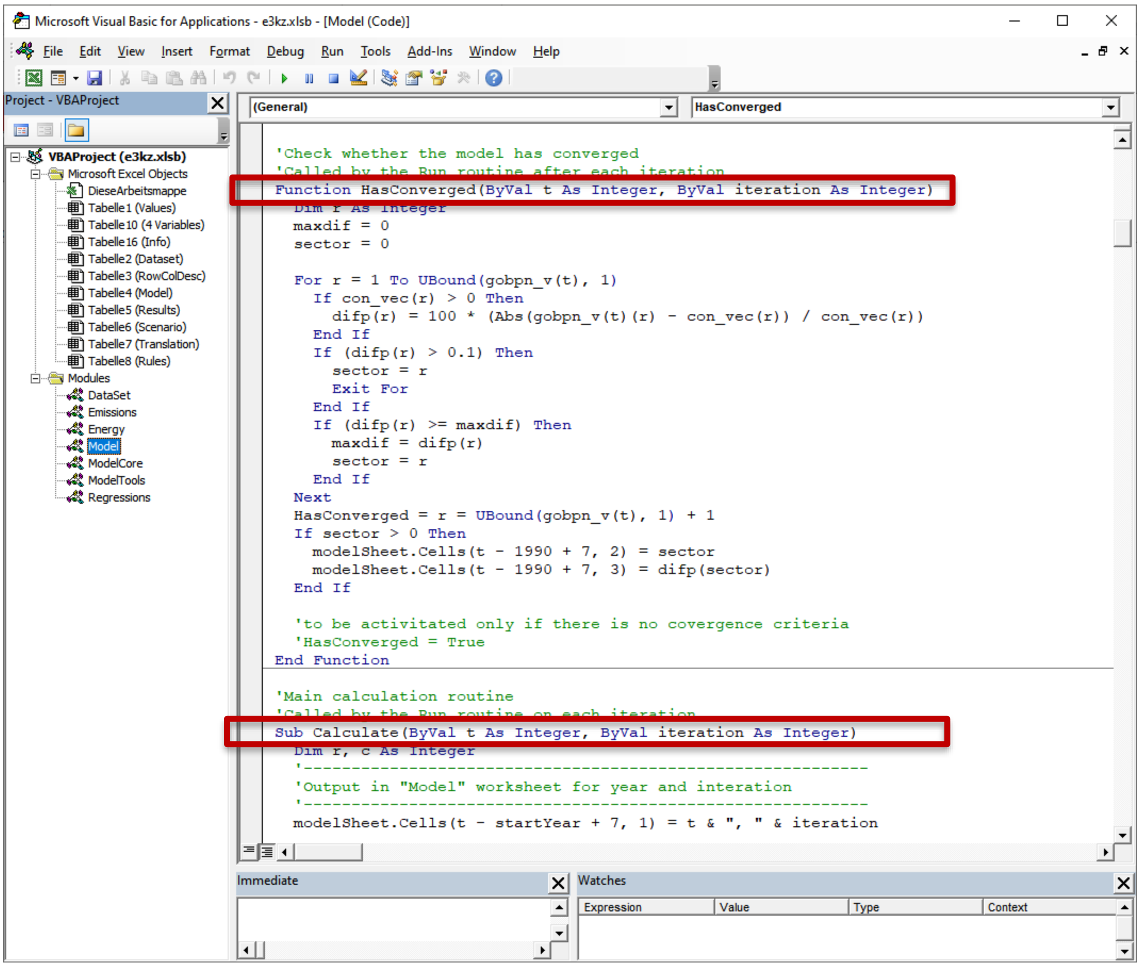


Figure 14: Calculate and HasConverged subroutines

Source: Own illustration.

The equation system consists of (mostly algebraic) statements which are processing the variables of the data set. Each of these variables is a time series, thus the first index of such a variable indicates the year *t* for which the data is read or written, e. g.

Labor force for year `t`: `lf_s(t)`

Elements of time series of vectors and matrices are accessed by providing the appropriate row (and column) indices. Examples:

- World market prices by fuels, row 1: world market price for crude oil, in 2015: `wmp_v(2015)(1)`
- Domestic input coefficients nominal for year *t* at row r and column c: `dicn_m(t)(r, c)`

Framework routines related to matrix algebra can be found in the Appendix 1.

In order to protect historical data from being overwritten, model builders should use the last data constants as shown in the following example:

```
If t > empl_v_lastData Then
     'some calculation
End If
```

By using these constants, model builders ensure proper model operation even after data updates as long as the data set properties have been carefully updated as well.

By providing the full set of equations in readable form, model issues can be tracked down much easier than in systems using so-called solvers: The model builder can set a breakpoint in the source and let the integrated debugger stop execution at any time. Once execution is paused, the current values of all variables may be inspected which greatly simplifies the process of model debugging.

Although it is technically possible to embed the full model code in the *Model* module, model builders are advised to logically separate the three E's of an E3 model by using modules. To keep the *Model* module clean and lean, it might be useful to also separate model-specific generic functions and store them in a separate module, e. g. *Model Tools*. One prominent example are aggregate routines for vectors / matrices.

The content of the different modules is discussed in chapter 3

2.7 Regression analysis with "R"

All behavioral parameters of the model are estimated econometrically, and different specifications of the regression equations are tested against each other, which gives the model an empirical validation.

Although Excel provides basic routines for estimation, usage of an dedicated external application is preferrable for the following reasons:

- Regression equations cannot be edited easily (cell ranges need to be marked and routed to the appropriate Excel functions)
- Regression graphs need to be prepared separately
- Different combinations of equations referring to the same variable cannot be easily stored
- Large dataset cannot be conveniently handled

Using an external application for regression analysis entails two problems: First, the historical data stored in the *Values* sheet in the model workbook must be accessible by the regression application (e. g. by transforming data into another file format). Second, regression results, i. e. coefficients, need to be transferred back into the model. For an elaborated model such as e3.kz, this cannot be efficiently handled manually. The DIOM-X modelling framework provides the necessary tools to tackle both problems automatically.

The software "R"[5] is widely used for all kinds of data-related research. Besides the rich set of available libraries, one of its main advantages is that it is an open-source application which may be used free of charge even in non-academic environments.

This section explains how "R" can be integrated into the model building process. It is assumed that the reader has basic knowledge in operating "R" and performing Ordinary Least Square (OLS) regressions with it. Furthermore, the "R" application must be already installed on the computer. It is available free of charge from

https://www.r-project.org/

"R" does not come with a developer-friendly user interface; it is therefore assumed that the addon software *R Studio* available free of charge from

https://www.rstudio.com/

is installed as well.

A very common estimation approach is the OLS method which yields a linear regression model by minimizing the sum of squared residuals, i. e. the difference between realized and predicted data points for the past. Statistical test measures were included in the evaluation of single regression equations. For individual variables the corresponding t-statistics are of major importance. These and their associated p-values allow for an evaluation of the statistical significance of the variable in question with respect to its impact on the dependent variable. The R^2, the so-called coefficient of determination, can be used to judge the quality of the regression model. It shows the proportion of variance of the dependent variable that is explained by the explanatory variables. In general, it holds that the higher the R^2, the higher the explanatory value of the model is. Different regression equations can thus be compared using the R^2 (or in the case of more than one explaining variable the adjusted R^2, which controls for the positive effect of additional explaining variables by imposing a penalty on the respective equation).

Before the OLS method can be applied, the e3.kz model data needs to be transferred to "R" first. Although "R" is capable of reading Excel files, it cannot easily interpret the e3.kz data set. "R" usually expects variables stored in columns which is not possible with larger datasets in Excel due to a strict limit in the maximum number of columns. To overcome this restriction, the DIOM-X framework provides an automatic conversion routine which exports the entire historical data set from the *Values* sheet into a format that can be conveniently read by "R" (and other statistical program packages such as EViews). The conversion process is triggered by clicking the *Export data for regressions* button (see Figure 15 and also section 2.4.3).

[5] "For an introduction in "R", please refer to various online documentations (e. g. https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf).

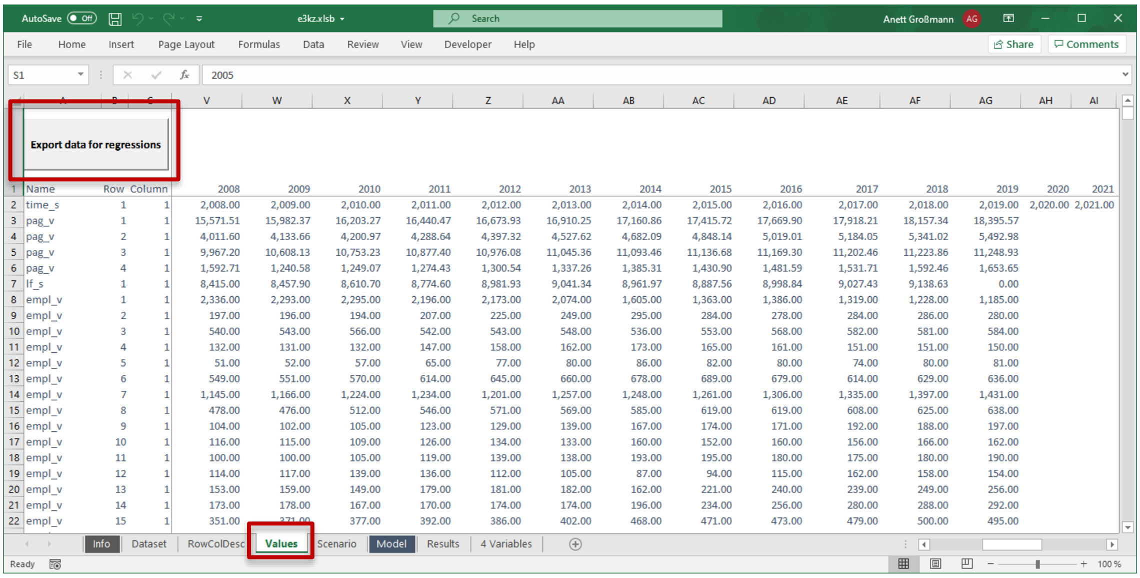


Figure 15: Values worksheet

Source: Own illustration.

The generated file *series.csv* includes the entire historical database and is stored in the folder *regs*. The folder is also used to store the different estimation equation files (e. g. sna.R) as well as the library *vbaLib*.R which provides helper functions for OLS estimation and translation of regression results back into the e3.kz model code (Figure 16).

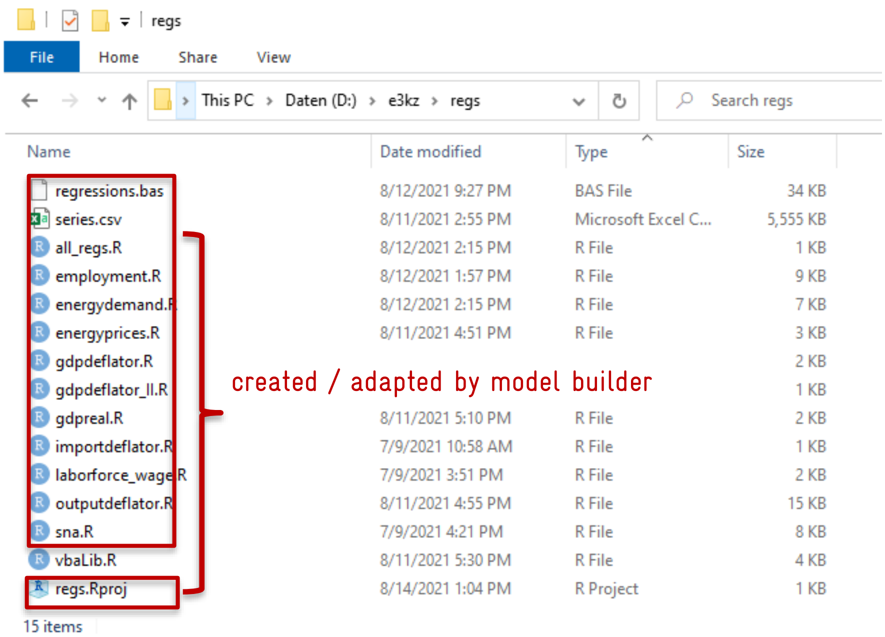


Figure 16: regs folder of e3.kz

Source: Own illustration.

Performing regression analysis as part of an E3 model is an iterative process. Throughout model runtime, the model iteratively solves the underlying equation system by checking a certain convergence criterion which must be fulfilled every year. Such a system usually behaves very sensitive to changes in the regression parameters. Thus, it is common practice that several regression specifications need to be tested in the context of the equation system to ensure model stability.

For most estimations, historical data is limited to a time period of around 15 to 20 years. In view of the long-term modelling horizon up to 2050, particular attention must be paid to the sign and magnitude of the parameters for the explanatory variables, and, of course, to the overall stability of the model. Estimated parameters can be further verified by a comparison with other studies and / or model exercises. The model should also reflect expectations regarding, e. g. economic development and energy demand, identified in other studies.

To perform regressions in "R" based on the exported data set in *series.csv*, the project file needs to be opened by double-clicking on *regs.Rproj* in the *regs* directory of the model. If this file type is not associated with "R" Studio, the file needs to opened manually (see Figure 17).

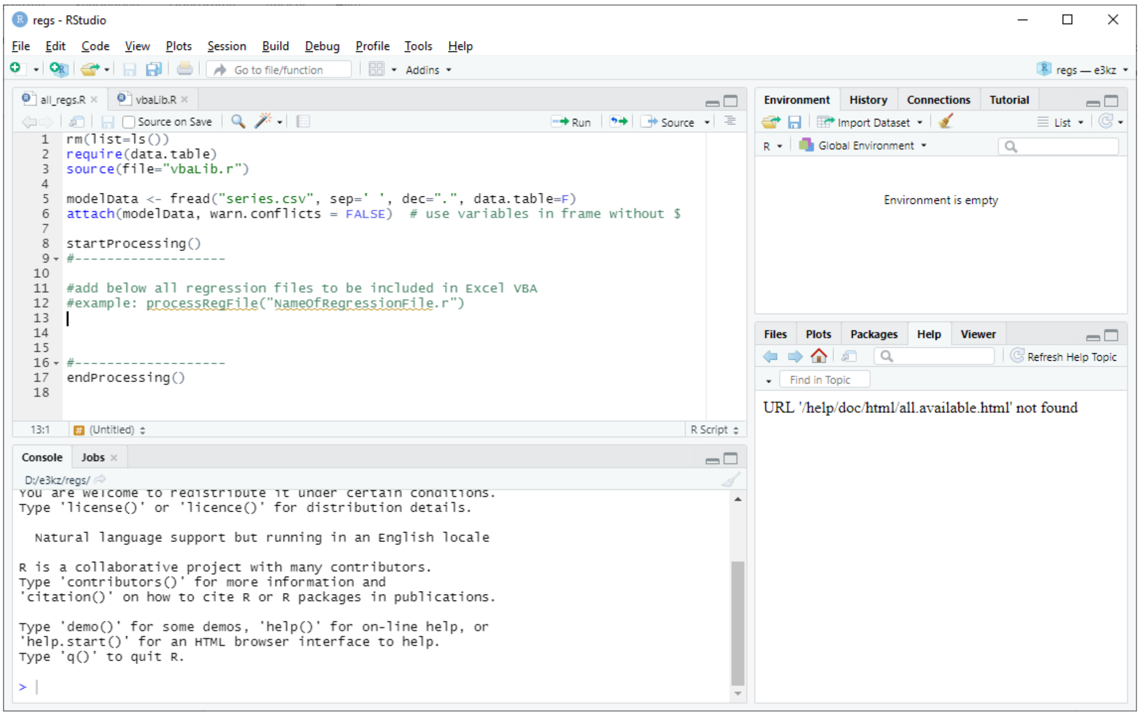


Figure 17: "R" graphical user interface

Source: Own illustration

The file *allRegs.R* is the master file which triggers all subsequent actions, i. e. loading of the data set and automatic translation of the estimation parameters into model code.

All regression files that need to be processed must be placed between the *startProcessing* and *endProcessing* function calls which ensure proper translation from "R" to VBA code.

This file needs to be executed if the dataset or any of the regression equations have changed to ensure that the latest changes will be reflected in the model.

The e3.kz model incorporates several variables (e. g. GDP components in constant prices and respective deflators, employment etc.) that are estimated. For each of them a "R" script is created including the specifications of the regression equations and, if necessary, statements for calculation of missing indicators[6] that are needed for estimation and are not part of the imported data set (Figure 18). Each regression file is named accordingly to the content. For example, in case of deflator for the GDP components, the regression file is named *gdpdeflator*.R and stored in the folder *regs*. This name will show up in the VBA code as well.

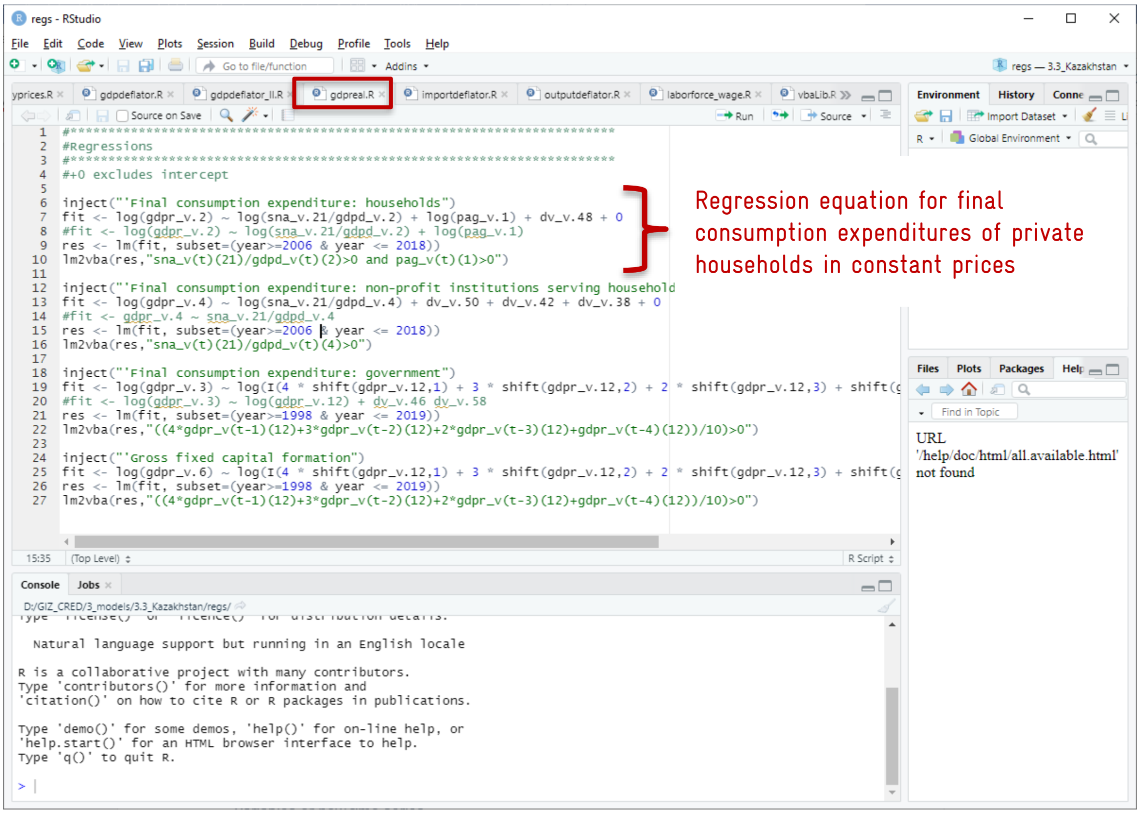


Figure 18: Regression examples

Source: Own illustration

Each regression equation needs the following statements

- *inject()*: This statement injects a comment into the VBA model code and should be used with each regression to explain the purpose/content of the regression
- *fit*: specification of the regression equation (Which explanatory variable(s) should be included? Linear regressions for linear relationships or linear regressions with logarithmic transformations for non-linear relationships?)
- *res <- lm(fit, subset = year >=… & year <=…)*: *lm* indicates that a OLS linear model is used; *subset* may be used to limit the range of years to which the regressions should be applied (observation period)
- *lm2vba(res,…)*: This function automatically translates the regression results into VBA code. All results are stored in a single file named *regressions.bas* which later will be inserted into the model.

[6] It must be noted that each additional indicator calculated in "R" must be also calculated in VBA. They are not automatically transferred to MS Excel / VBA.

In the bottom left pane (see Figure 19), various regression specifications can be tested. Results of statistical tests can be shown with *summary()*. Various "R" packages provide further options to analyze and visualize the results which is not part of that manual but can be explored in "R" blogs and fora.

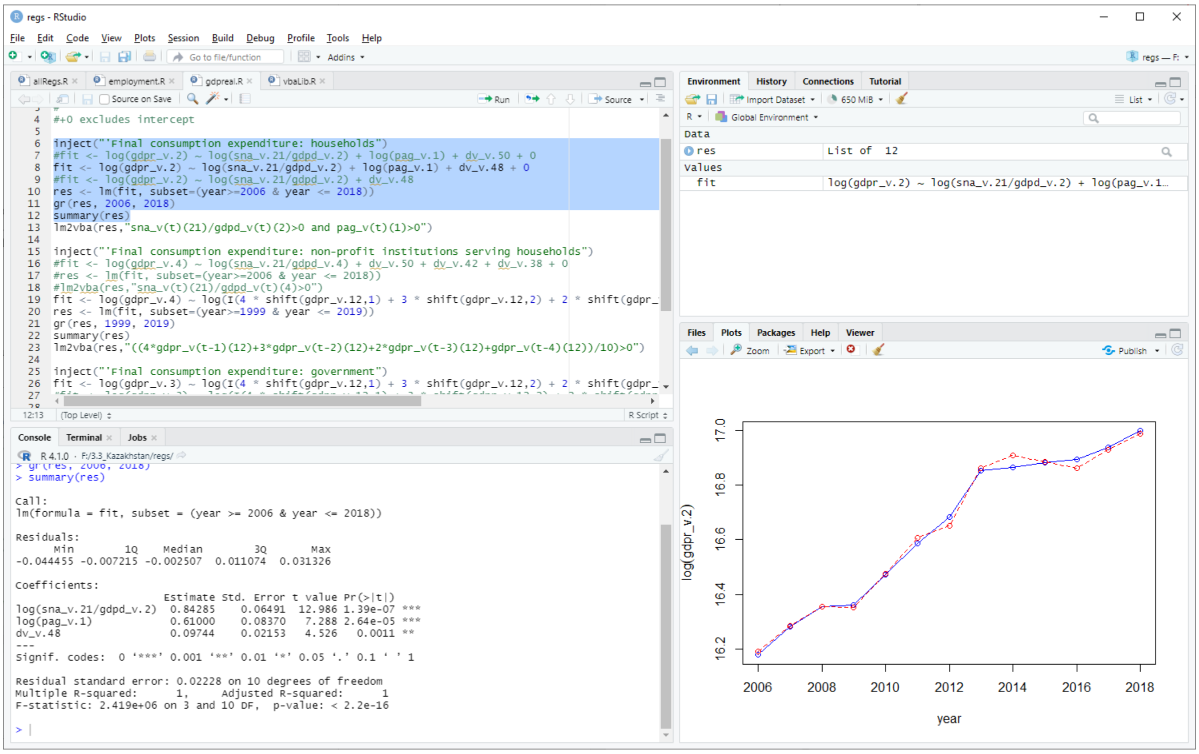


Figure 19: Overview of statistical test results using summary()

Source: Own illustration.

The library file *vbaLib.r* which is automatically loaded by the *allRegs.R* master file contains additional helper functions which simplify formulating equations but are not necessarily used in every equation. The most important are the following:

- *group*: Creates a group of variables based on the given "name", i.e. useful for vectors
- *combine*: Creates a combined variable based on name and range of rows
- *gr*: Plot a regression with optional time span

Usage of these functions can be derived from studying any of the regression files, e. g. *gdpdeflator.R* (see Figure 20).

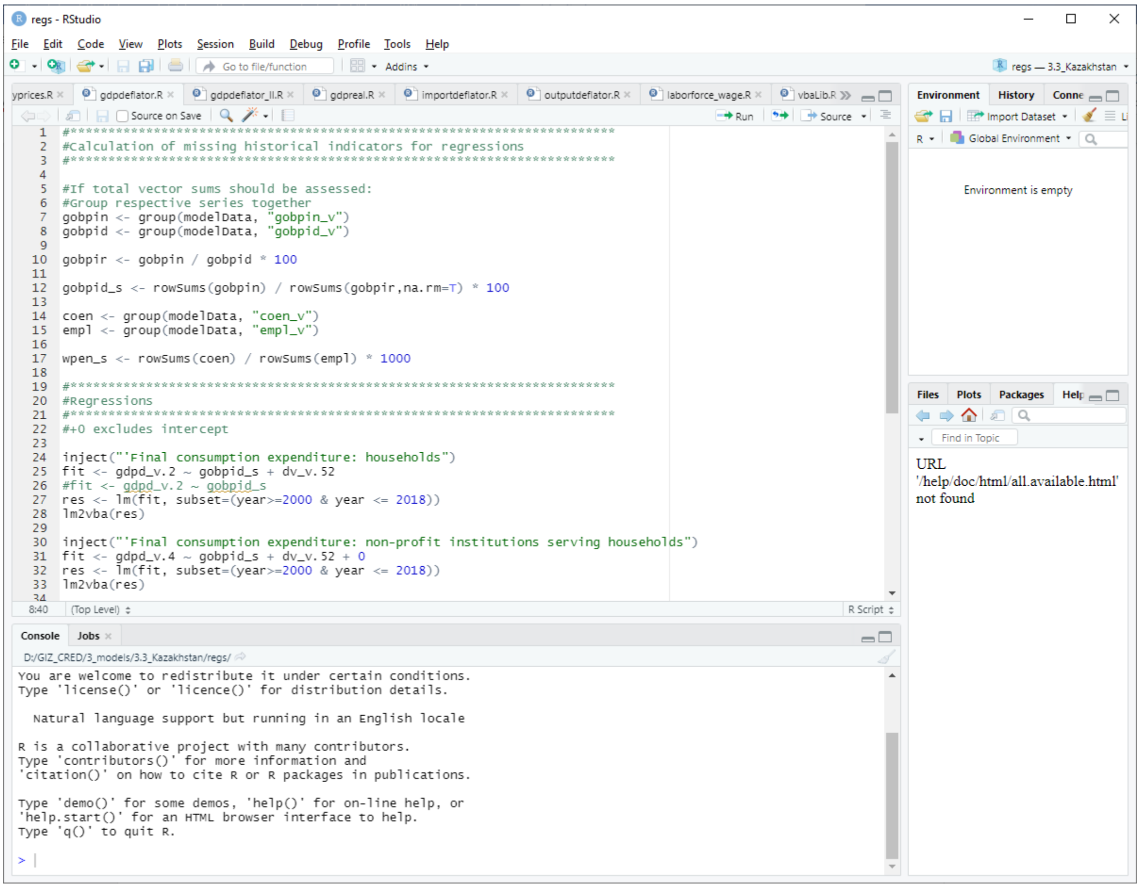


Figure 20: Helper functions in vbaLib.R

Source: Own illustration.

After all model variables are estimated and final regression equations are formulated in the respective "R" files, these file names must be included in *allRegs.R* for automatic translation into VBA code. Once this file is executed (Ctrl+Shift+Enter), the file *regressions.bas* is created including all regression equations with their parameters. This file must be integrated into VBA (Figure 21).

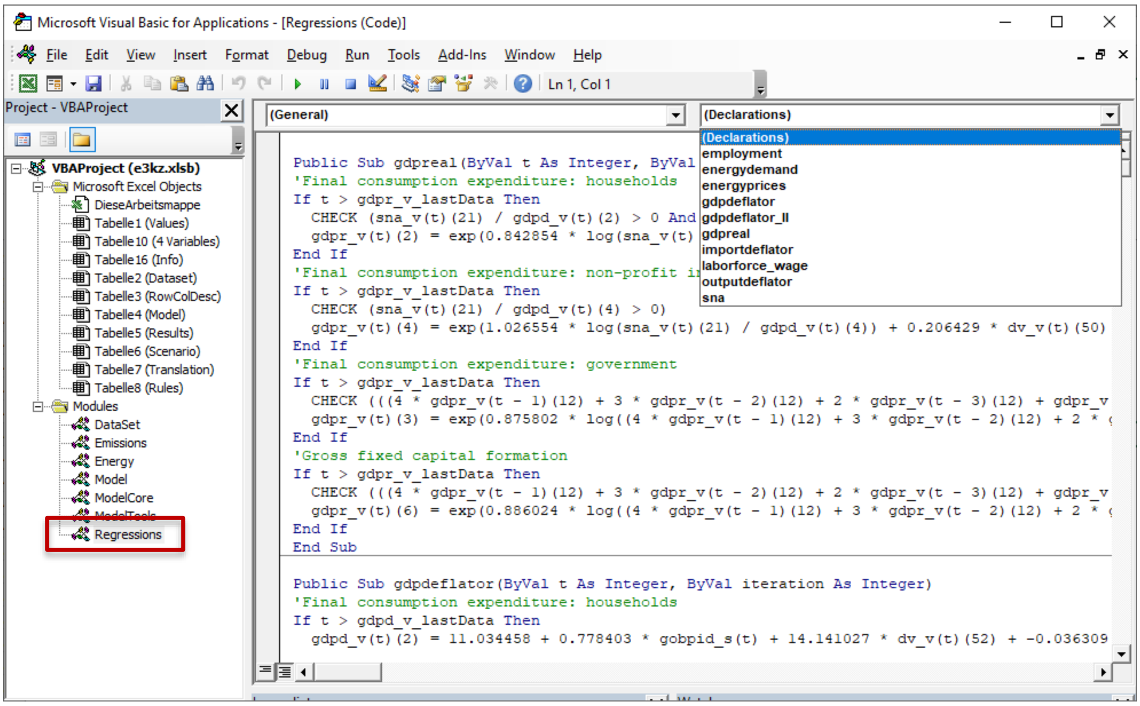


Figure 21: Regression module

Source: Own illustration.

The necessary steps to import the module containing the regression equations and parameters are as follows:

1. Select the *Regressions* module in the left pane of the VBA programming environment:

2. Right-click and select *Remove Regressions*. Removing the old version is unfortunately necessary because Excel will not update the existing version but create another module with a different name.

3. Right-click again, select *Import file* and import the file *Regressions.bas* from the folder *regs* where the workbook is stored.

3. E3.KZ – AN ECONOMY • ENERGY • EMISSION MODEL FOR KAZAKHSTAN

E3.kz is a model covering the demand-and-supply-relationships of the Kazakh economy and its main connections to the environment, i.e. the use of energy resources and the input of CO_2 emissions into the environment.

Figure 22 briefly shows the three model parts and its interrelations. Number 1 indicates the economic core of the e3.kz model, number 2 shows the energy module and number 3 the emission module.

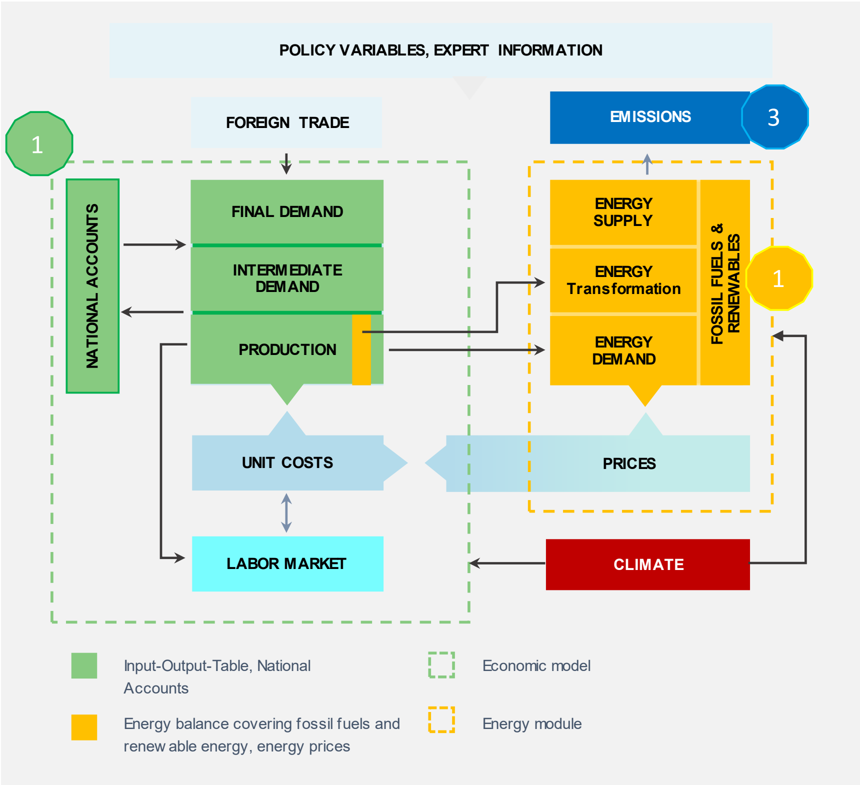


Figure 22: E3.kz model overview

Source: Own illustration

Each of the three parts are based on a rich and up-to-date dataset given as time series based on annual data which allows for deriving model relationships empirically. Apart from deterministic calculations such as the relations given by the IO framework, econometric methods and expert knowledge are used to derive future developments from historical data. The results depend on some exogenous inputs (e. g. population, world market prices) and the modelled relationships within the three model parts and between them.

The details of each of the three model parts are depicted in the subsequent sections. In the section "Implementation into DIOM-X", code snippets are explained using specific examples. The full model code is part of the *e3kz.xlsb* workbook.

3.1 Folder structure of e3.kz

It is meaningful for model builders to create a model folder structure that reflects the main model building steps[7] (Figure 23) although model users finally only need the workbook *e3kz.xlsb* to run simulations.

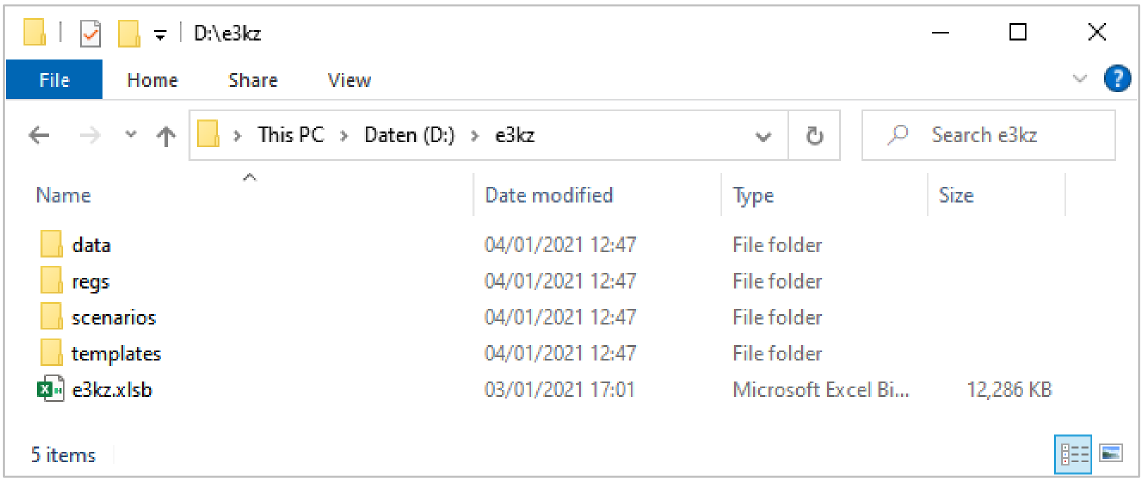


Figure 23: Folder structure of e3.kz

Source: Own illustration

The folder *data* contains the historical data collected from official statistics[8]. With large data sets, it is useful to create subfolders to group the data, e. g. by institutional data providers (COMSTAT, IEA, World Bank) and – if necessary – also by content (e. g. population, IO, SNA). The data sets specified in each E3 subsection (see for example section 3.2.2) can be easily found according to the subfolder structure organized by data providers.

All e3.kz data are included in the *Values* worksheet. It is only necessary to store original data files in the *data* folder if the original data is linked to the *Values* sheet.

In the folder *regs,* all files needed for the regression analysis are stored. Regressions are done in an external regression program such as "R", but need of course the historical data set stored in the file *series.csv*. Also, the tested regression approaches and resulting final regression equations including the coefficients (*regressions.bas*) are stored in that folder so that the model builder can easily insert these into the VBA code.

The folder *scenarios* contains all scenarios (including tweaks and results) and the evaluation file for comparing two scenarios (_Compare2Scenarios_.xlsb).

The folder *templates* includes MS Excel templates with tables and graphs which are used by default for scenario evaluation. These templates may be further customized.

[7] The model code is stored in the *e3kz.xlsb* workbook and therefore no dedicated folder exists.
[8] Using data from official statistics supports transparency, ensures regular data updates, assures high degree of quality.

3.2 Economic model

3.2.1 General overview

The economic part of the e3.kz model is a macro-econometric (or dynamic) IO model. The underlying modelling approach is based on the INFORUM approach (Almon 1991, 2014). These models exist in different forms and degrees of complexity (see e. g. Eurostat 2008, pp. 527, Stocker et al. 2011, Lehr et al. 2016, Großmann, Hohmann 2016, Lewney et al. 2019).

The economic core of the model is based on the top-down approach. Top-down means that first, the GDP components of final demand (expenditure approach) – amongst others – of private households, government as well as investments and exports are determined entirely and then are disaggregated by using product (goods and services) groups of the respective variable.

As with static IO models[9], the IO relationships are the core of this macro-econometric IO model. This model type is typically demand-side driven. However, the demand is determined within the model and not given exogenously. The economic cycle (production – income generation – redistribution – consumption) is represented by the system of national accounts (SNA). An important variable in the SNA is disposable income, which is influenced by both the current labor market situation and the redistributive activities of the government through taxes and subsidies. In addition to other variables such as purchasers prices, disposable income is an important determinant of private consumer demand.

The link between demand and supply is given by the Leontief production function (as represented in the IO table) which shows the selling and cost structure for each production unit. The latter is represented by the need for input factors (intermediate demand) and labor (primary inputs such as compensation for employees, net taxes on production).[10] Prices are derived by using a unit cost approach considering the cost components. Production prices plus net taxes on goods determine purchasers prices.

In contrast to simple static IO models, the volume and price reactions in this macro-econometric IO model are empirically-based and take the passing on of costs into account. Using econometric methods allow for imperfect markets and bounded rationality (Meyer and Ahlert 2016). Thus, e3.kz is not a Computable General Equilibrium (CGE) model where prices balance supply and demand.[11]

Supplementary data are population by age groups, employment and wages by economic activities. Population at working age determines the work force. Labor demand is determined at sector level and related to real production and wages by economic sectors. Increasing real wages tend to lower employment while a higher production level will increase employment. The macroeconomic wage rate is determined by using a Phillips curve approach.

The economic model contexts shown in Figure 24 are captured via identities (e. g. in the IO context; solid lines), behavioral equations that are empirically validated (dashed line) and a few exogenously given variables (yellow marked) such as population. However, the specification of the model is not finished with the estimation of single equations. The complete, non-linear, interdependent model equation system is solved

---

[9] The structure of an IO table and a basic introduction into IO analysis is given in the section Excursion: IO analysis.

[10] Capital goods (buildings, machinery, vehicles, intellectual property, livestock and crops) are other production factors which are not explicitly considered in the current stage of the model e3.kz.

[11] The COVID19 pandemic has shown that the assumption of market clearing prices does i. e. not hold if business are closed and supply shortages prevail.

iteratively for each year. The iteration process finishes once a given criterion is fulfilled. This criterion has to be an endogenously calculated model variable which for e3.kz is the output by economic sectors. As long as the model has not converged, all model equations are recalculated for the current year (cf. 2.6.2 and 2.6.3). Afterwards, all equations are solved year by year until the end of simulation period which was set at 2050.

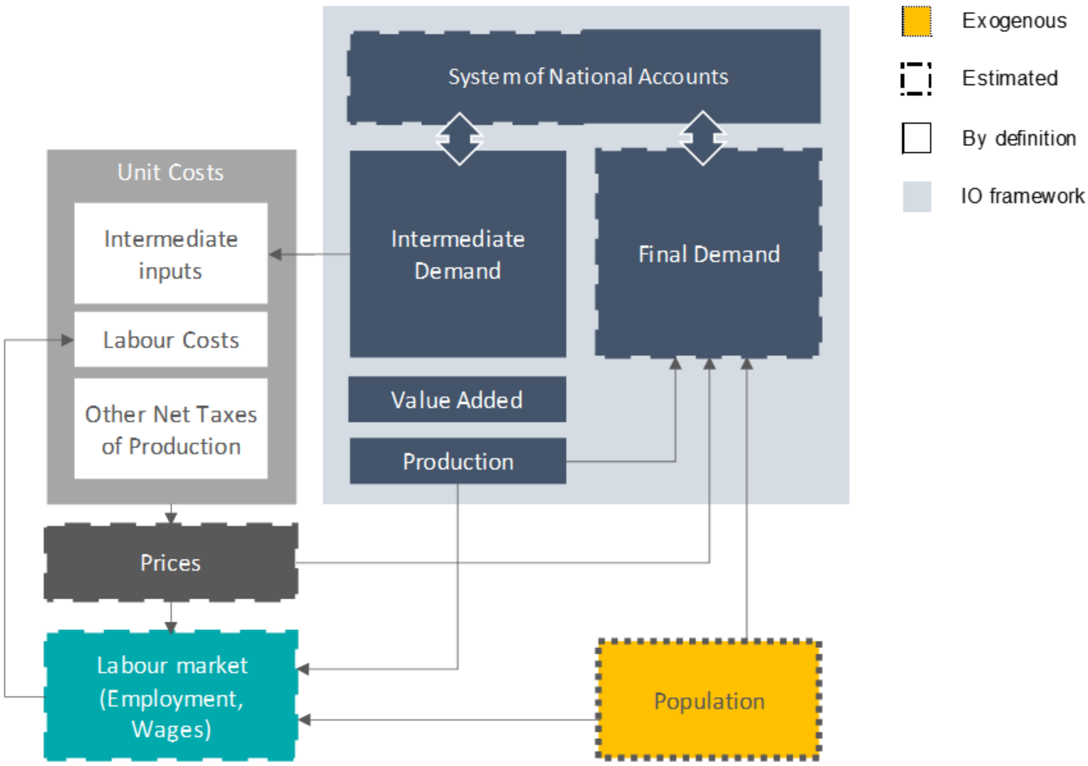


Figure 24: Simplified illustration of the macro-econometric IO model

Source: Own illustration

Exogenous impulses for the model are, for example, population development and ex-ports, which trigger adjustment reactions in the highly interdependent model. The modelling approach which covers not only quantity effects but also income and price effects, provides multipliers that determine the dynamics of the system:

- Leontief multiplier: shows the direct and indirect effects of demand changes (e. g. consumption, investments) on production;
- Employment and income multiplier: Increased production leads to more jobs and thus higher in-comes resulting in higher demand (induced effect);
- Investment accelerator: Indicates the necessary investments to maintain the capital stock needed for production based on the demand for goods.

3.2.2 Data set

The economic model is based on the following data set which is published by the Committee on Statistics of Ministry of National Economy of the Republic of Kazakhstan (COMSTAT) and the National Bank of Kazakhstan (Table 2).

Table 2: Data set for the economic model

Macroeconomic and Socioeconomic Data		
Population (by age groups)	Total population from Kazakh Statistical Committee (KSC), 1991-2023	COMSTAT
Labor market	Total employment, unemployment (2001-2023) Total labor force (2001-2023) Total / Average wages (2010-20122) Unemployment rate (2001-2023)	COMSTAT
	Exchange rate (national currency/ USD; 1993-2023)	World Bank
GDP and components	GDP by components (in current and constant prices, deflator) available from 1993-2023	COMSTAT
Annual national accounts	Sequence of accounts for the total economy (2006-2022)	COMSTAT
Sectoral Data		
Input-output table	sym. IOT (intermediate and final demand, primary inputs; domestic and imported separately; 2012-2022), supply and use tables	COMSTAT
Trade	Imports and exports (2012-2022)	COMSTAT
Sectoral price indices	Production and import price indices (1998-2018)	COMSTAT
Labor market	Employment by 21 industries (2001-2023) Compensation of employees by 72 industries	COMSTAT

Source: Own illustration

3.2.3 Implementation into DIOM-X

The detailed illustration of the macro-econometric IO model as implemented into the model building framework DIOM-X shows Figure 25. The description of the model variables is given in the worksheet *Dataset* in the workbook *e3kz.xlsb*.

The projection of the values of each model variable is either given exogenously (following other projections (yellow color), remains unchanged as indicated by the dotted lines), is specified endogenously in regression equations (dashed lines), is calculated by growth rates (blurred color) or is given by definition (solid lines).

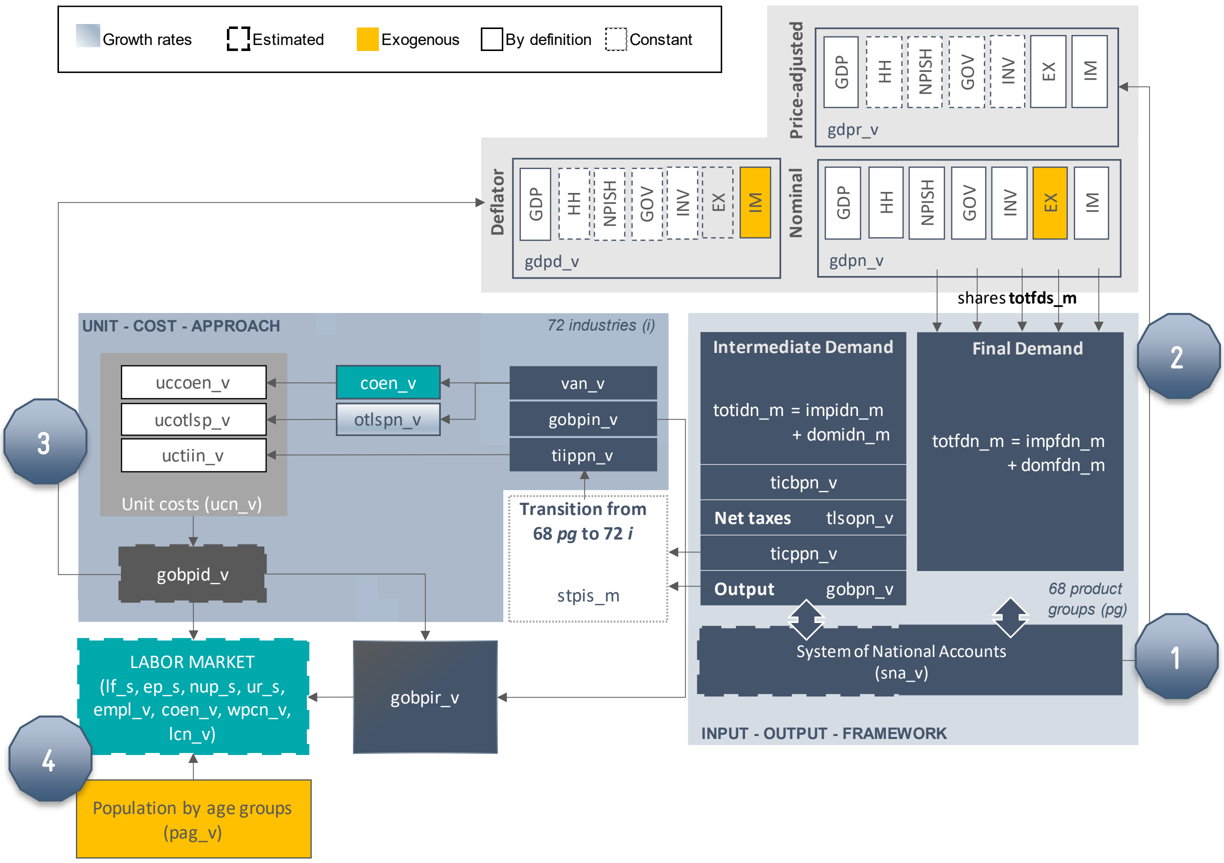


Figure 25: Detailed illustration of the macro-econometric IO model

Source: Own illustration (all variable names are described in the e3kz.xlsb *Dataset* worksheet)

The e3.kz model is based on a top-down approach. Economic growth is determined first at macro level by modelling quantity and price relationships and then broken down to the industries (top-down approach). The final demand components – either price-adjusted values or nominal values as well as deflators – are determined at macro level: Price-adjusted final consumption expenditures of households *gdpr_v(2)*[12] is estimated[13] with real disposable income *sna_v(21) / gdpd_v(2)* and population *pag_v(1)*. While increasing disposable income positively affects consumption, an overall consumer price increase affects it negatively. Population growth impacts consumption expenditures positively.

---

[12] Values in "()" indicate the row (and column) elements of a vector (labelled with r) or a matrix (labelled with r and c) which could be the number of given GDP components or the number of product groups given for an economic variable such as import deflator. For the description of rows and / or columns, please refer to the Appendix 2 to Appendix 8 or the worksheet RowColDesc in the workbook e3kz.xlsb.

[13] All estimations are done in "R" and results are then inserted into the VBA code. In section 2.7, the steps to be taken to implement the regression results into VBA are described.

```
"R" code

inject("'Final consumption expenditure: households")
fit <- log(gdpr_v.2) ~ log(sna_v.21/gdpd_v.2) + log(pag_v.1) + 0
res <- lm(fit, subset=(year>=2006 & year <= 2022))
lm2vba(res,"sna_v(t)(21)/gdpd_v(t)(2)>0 and pag_v(t)(1)>0")


VBA regression function

Public Sub gdpreal(ByVal t As Integer, ByVal iteration As Integer)
  ' Final consumption expenditure: households
  If t > gdpr_v_lastData Then
    CHECK (sna_v(t)(21) / gdpd_v(t)(2)) > 0 And (pag_v(t)(1)) > 0 Then
     gdpr_v(t)(2) = exp(0.842854 * Log(sna_v(t)(21) / gdpd_v(t)(2)) + 0.610004
                        * Log(pag_v(t)(1)))
    End If
  End If
  ...
End Sub

Call of regression function in model code
gdpreal t, iteration
```

Disposable income *sna_v(21)* is determined in the SNA. Price-adjusted final consumption expenditures of non-profit institutions serving households *gdpr_v(4)* is determined by real disposable income *sna_v(21) / gdpd_v(4)* by using the respective deflator *gdpd_v(4)*.

The regression equation(s) are included as VBA functions in the model code. The name of the function *GdpReal* is identical to the name of the file including the estimation equation(s) (see *regs* folder).

```
GdpReal t, iteration
```

Price adjusted government consumption *gdpd_v(3)* depends on the development of a weighted moving average of the price-adjusted GDP *gdpr_v(12)* assuming that the government can spend more in its fields of activity when wealth is increasing. The weighted moving average implies that most recent GDP growth has a higher impact on consumption decisions than previous years. Gross fixed capital formation *gdpr_v(6)* is a function of a weighted moving average price adjusted gross domestic product *gdpr_v(12)*.

The deflators for the GDP components *gdpd_v(r)* – except for imports and exports – are estimated with the total output price *gobpid_s* which in turn is calculated by a unit cost approach. The export deflator *gdpd_v(9)* is determined by both the total output price and the world market price for crude oil *wmp_v(1)* given in USD per Barrel and the exchange rate KZT / USD *exra_s*. Crude oil exports account for around 50% of all ex-ports and the price is set at the world market.

Import deflators by product groups *impd_v(r)* follow their own trends or the world market prices. Import deflators can also be adjusted by the model users to capture the impact of the valuation of the Kazakh Tenge as observed during the COVID19 pandemic.

Nominal GDP components *gdpn_v(r)* are basically derived from deflators *gdpd_v(r)* and corresponding price-adjusted values *gdpr_v(r)*. By using the VBA *UBound* function, the upper bound of an array (here for the variable *gdpn_v* which is specified in the worksheet Dataset) is returned.

```
For r = 1 To UBound(gdpn_v (t), 1)
  gdpn_v(t)(r) = gdpr_v(t)(r) * gdpd_v(t)(r) / 100
Next
```

An exception exists for exports *gdpn_v(9)* which are given exogenously by using the tweak mechanism (cf. section 2.4.5).

```
Tweak t, gdpn_v_lastData, gdpn_v, "gdpn_v"
```

The GDP deflator is calculated by definition as the ratio of nominal GDP and price-adjusted GDP.

2

The transition from the domestic concept (GDP expenditure approach) to the national concept (total final demand *totfdn_m(r,c)*) occurs under consideration of direct purchases abroad by residents *totfdn_m(t)(69, c)* and non-residents *totfdn_m(t)(70, c)*. The total values of each final demand component are distributed to the single industries by using constant shares *totfds_m(r,c)* calculated for the history (until *lastData*, see VBA code below). Total final demand is given as a matrix and thus has rows *r* and columns *c*. For each column *c* of the matrix *totfdn_m(t)*, the shares for the row elements 1 to 68 are calculated.

```
If t <= totfdn_m_lastData Then
  For c = 1 To UBound(totfdn_m(t), 2)
    For r = 1 To 68
      totfds_m(t)(r, c) = totfdn_m(t)(r, c) / (totfdn_m(t)(71, c) -
                          totfdn_m(t)(69, c) - totfdn_m(t)(70, c))
    Next
  Next
End If
```

Additionally, total final demand *totfdn_m(r,c)* is divided into domestic *domfdn_m(r,c)* and imported final demand *impfdn_m(r,c)* by applying historically observed import shares by component. In scenarios, these rigid specifications can be varied and both the share of a product in the respective total and the import share per product of final demand can be adjusted.

Production-induced imports *pii(r)* – which are based on domestic production – are calculated by the formula *pii = iicn_m * (i_m(r,c) – dicn_m)-1 * tfdd*

with: iicn_m - Imported input coefficients, nominal

i_m - Identity matrix

dicn_m - Domestic input coefficients, nominal

tfdd - Total final domestic demand

For the matrix calculations DIOM-X offers a set of matrix algebra functions (see Appendix 1). The following functions are used for the calculation of production-induced imports:

- MatMult(matrix1, matrix2) which multiplies two matrices
- MatInv(matrix1) which inverts a matrix
- MatSub(matrix1, matrix2) which subtracts two matrices

```
pii = MatMult(iicn_m(t), MatMult(MatInv(MatSub(i_m, dicn_m(t))), tfdd))
```

The sum of imported final demand and production-induced imports results in total im-ports *impfdn_m(r,11)* which have to be subtracted from total final demand *totfdn_m(r,10)* before entering the Leontief equation $(i\_m, ticn\_m)^{-1}$ from which the output by product groups *gobpn_v(r)* can be derived.

```
For r = 1 To 68
  tfdei(r) = totfdn_m(t)(r, 10) - impfdn_m(t)(r, 11)
Next
gobpn_v(t) = MatMult(MatInv(MatSub(i_m, ticn_m(t))), tfdei)
```

Both output *gobpn_v(r)* and intermediate consumption *ticbpn_v(r)* by product groups calculated from the IO framework need to be transferred to the economic activities (*gobpin_v(r)* and *tiippn_v(r)*) which corresponds to the economic sector data[14]. The supply table provides a detailed overview of transactions in goods and services by economic sectors which is used as transaction table *stpis_m(r,c)*. Value added *van_v (r)* is simply the difference between the previously mentioned variables which is calculated for all vector elements automatically by using the *VecSub* function provided by the DIOM-X framework.

```
van_v(t) = VecSub(gobpin_v(t), tiippn_v(t))
```

3

The value added components compensation of employees *coen_v(r)*, and other taxes less subsidies on production *otlspn_v(r)* are determined in the modelling context. It is assumed that the latter variable changes accordingly with production *gobpin_v(r)* by applying the growth rates.

```
For r = 1 To UBound(otlspn_v(t))
  otlspn_v(t)(r) = otlspn_v(t - 1)(r) * gobpin_v(t)(r) / gobpin_v(t - 1)(r)
Next
```

[14] While the product groups subdivided in 68 elements, the economic sectors consist of 72 elements. Thus, the classifications must be transferred to the other. The (dis)aggregation routines are described in the Appendix 18.

Compensation of employees depends on the number of employed persons *empl_v(r)*[15] and wages per capita *wpen_v (r)*. Intermediate inputs *tiippn_v(r)*, compensation of employees and other taxes less subsidies on production are cost components to be considered in the unit costs calculations.

Unit costs *ucn_v(r)* are defined as costs per unit of price-adjusted output by economic sectors *gobpir_v(r)* while r represents all economic sectors (here: 1 to 72) as given by the data set. Most important cost components are labor costs *uccoen_v(r)* and intermediate costs *uctiin_v(r)*. The labor costs for each economic activity are calculated from the total compensation of employees and the price-adjusted output at sector level. The intermediate costs are calculated from the price-adjusted intermediate inputs – differentiated by imported *iicr_m(r,c)* and domestically produced products (*ticr_m(r,c) - iicr_m(r,c)*) – purchased by an economic sector and valued with the import price *impd_v(r)* respectively output price *gobpid_v(r)*.

Output deflators *gobpid_v(r)* are estimated by total costs *ucn_v(r)* at sector level. The magnitude of mark-up pricing depends on the predominant market structure. In monopolistic markets, the profit margin tends to be higher than under competition.

4

Labor supply is modelled at an aggregate level. Demographic development, i. e. population at working age *pag_v(3)* determines labor force *lf_s*. A wage rate per capita over all economic sectors *wpen_s* is calculated as a function which forecasts the result of the bargaining process between the unions and the firms: Macroeconomic labor productivity *gdpr_v(12) / empl_s*, the consumer price index *gdpd_v(2)* and, if suitable, a labor scarcity indicator *lf_s/empl_s* determine the macro wage rate *wpen_s*, which, in turn, drives the wage rates per employment for all industries *wpen_v (r)*.

The number of employed people for 21 economic sectors *empl_v(r)* is estimated by the price adjusted output *gobpir_v(r)* and real wage rates given as the ratio of wage per employment and output price index *wpen_v(r)/gobpid_v(r)*, if significant.

The system of national accounts (SNA) is an integral part of the modelling system which allows for modelling the complete economic circuit and the monetary flows from production to consumption. Important variables derived within the SNA are, for ex-ample, the disposable income *sna_v(21)* and net lending/ net borrowing.

Many variables from the IO framework such as value added, final consumption expenditures, gross fixed capital formation etc. serve as input into the SNA. Other SNA variables such as social contributions and savings are determined within the system either by estimation them or by definition (see

Appendix 9).

[15] COMSTAT provides the number of employed persons for 21 economic sectors. To derive the compensation of employees for all 72 economic sectors, employment must be disaggregated into 72 economic sectors by assuming that the labor productivity of the 21 economic sectors is the same for respective sub-sectors. The aggregation of 72 to 21 economic sectors follows the specifications given in

Appendix 17.

3.3 Subnational extension of the economic model

3.3.1 General overview

The subnational modelling is based on an empirical analysis of regional economic structures and a systematic analysis of sector-specific growth differences between subnational regions and the national level in Kazakhstan. This extended modelling is embedded in the consistent, integrated macroeconomic e3.kz model which enables a comparative analysis of economic indicators such as employment and gross regional product with other subnational regions (Figure 26). The subnational extension was implemented for economic indicators, not for indicators of the energy module. Overall, 20 subnational regions are now covered by the subnational extension which includes the new regions of Kazakhstan such as Ulytau and Zhetysu.

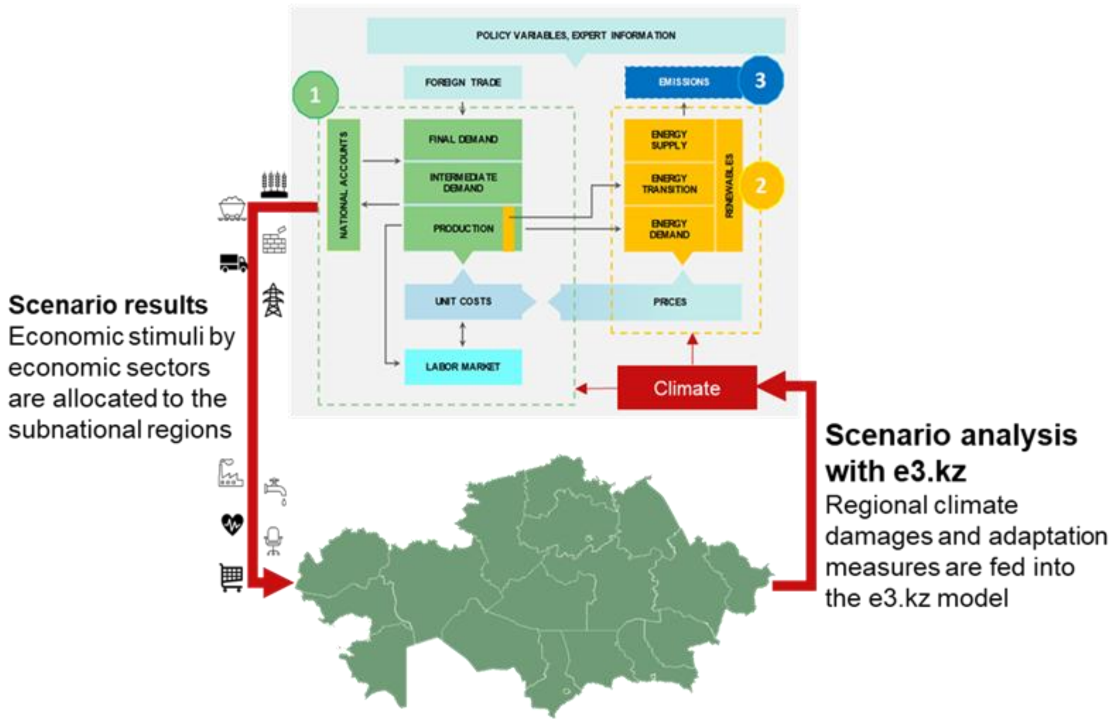


Figure 26: Subnational modelling

Source: Own illustration. Maps are from www.simplemaps.com

The regionalization approach follows the “shifted share” approach, which has already been successfully applied for regionalization down to the district level in Germany (Zika et al 2023). This approach allows both the transfer of sector-specific trends at the national to the subnational level and the consideration of regional disparities.

In the "shifted share" approach, the share of all economic sectors of a subordinate region in the superordinate region is first determined based on historical data. A comparison of these shares shows either similar or divergent developments in the respective region and the national average. Reasons for strongly divergent developments are, for example, location factors in a region that lead to relocations of companies in one sector to another region. Exceptional / atypical developments are not taken into account when determining the observed average “competitive advantage factors” (Zika et al. 2023, Bernardt et al. 2020).

These empirically derived factors for each region and economic sector are applied to project the historical regional, sector-specific employment based on the employment projections at national level. It should be considered that regional competitive advantages once gained can disappear again in especially in the long-term. Thus, it is assumed that the "competitive advantage factors" will gradually decrease.

For policymakers, another important economic indicator is value added or the gross domestic product. To derive value added by economic sectors, the regional, sector-specific labor productivity – which develops as the labor productivity at national level – is applied to regional employment. Finally, gross regional product can be determined by adding up the sectoral value added considering net taxes on products. For all regional economic indicators, the national values are determined by aggregation across all regions.

With the "shifted share" approach presented here, regional employment, value added and gross regional product can be consistently linked to the corresponding e3.kz model variables.

3.3.2 Data set

The subnational extension of the economic model is based on the following data published by COMSTAT (Table 3). The subnational classification follows the NUTS1 level (see

Appendix 19).

Table 3: Data set for the subnational extension of the economic model

Macroeconomic and Socioeconomic Data		
Population	Total population by regions (2000-2024)	COMSTAT
Labor market	Total employment by regions (1998-2023)	COMSTAT
Gross regional product (GRP)	GRP in current prices (1995-2023)	COMSTAT
Sectoral Data		
Labor market	Regional employment by 19 economic activities (1998-2023)	COMSTAT
Value added	Value added by economic sectors (2000 / 2010-2023)	COMSTAT

Source: Own illustration

3.3.3 Implementation into DIOM-X

In the *regio* module, population, GRP as well as employment and value added by economic sectors are projected by linking them to the corresponding economic indicators of the economic model (c.f. section 3.2, Figure 27). The projection of the regional (socio-) economic indicators is explained in the next paragraphs.

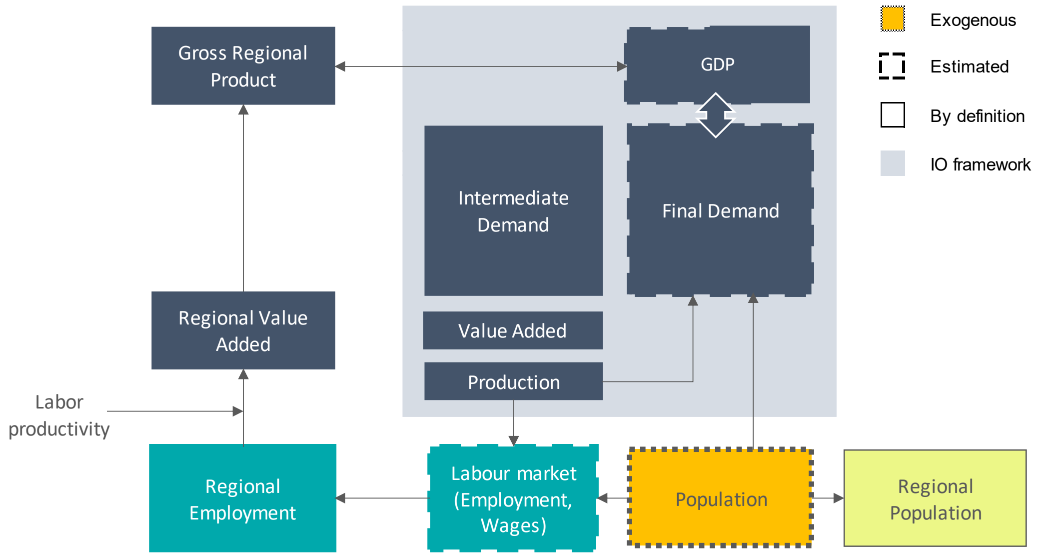


Figure 27: Detailed subnational modelling scheme

Source: Own illustration. Maps are supported by Bing © Microsoft, TomTom, Wikipedia.

Future **population** development at national level is from ERI demographic model calculations . To get an idea of how population at subnational level might develop until 2050, it is assumed that each of the 20 regions contributes to national population growth as in the past.[16]

First, the contribution to population growth at national level for each region *pcgnl_v(r)* is calculated based on the time series data for regional population *pr_v(r)* and total population at national level *pag_v(1)*:

```
For r = 1 To UBound(pr_v(t), 1)
  If pag_v(t)(1) > 0 Then
    pcgnl_v(t)(r) = (pr_v(t)(r) - pr_v(t - 1)(r)) / pag_v(t)(1) * 100
  End If
Next
```

In a next step, the average annual contribution to population growth *paacgnl_v(r)* is determined excluding outliers. The resulting indicator is then applied to project regional population considering that in particular in the long-term, the observed growth contribution may decrease over time.

[16] This projection can be replaced by subnational population projections once available.

Employment by 20 economic activities is the link between the national and subnational level given the data available. To transfer the sector-specific employment trends from the national *empl_v(r)* to the subnational level *emplr_m(r,c)*, first, the share of regional employment by economic sector in sectoral employment at the national level is determined based on historical time series data. For each historical year, the ratio of these shares shows either similar (ratio equals 1) or divergent developments (ratio differs from 1) in the respective region compared to the national average (see also Bernardt et al. 2020, p. 82). Shifted shares greater (smaller) than 1 indicate that a region may have a "competitive advantage" ("competitive disadvantage").

```
For c = 2 To UBound(emplr_m(t), 2)
  For r = 2 To UBound(emplr_m(t), 1)
    ess_m(t)(r, c) = (emplr_m(t)(r, c) / emplr_m(t - 1)(r, c)) /
                     (empl_v(t)(c - 1) / empl_v(t - 1)(c - 1))
  Next
Next
```

In a second step, atypical shares are excluded from the calculation of the average shifted share by region *r* and economic sector *c eass_m(r,c)* over the historical period. To do so, the time series of the shares by regions and economic sectors are sorted by size using the "quicksort" algorithm and then, the values in the first and tenth decile are excluded from the calculation of the average shifted share.

In a last step, the average shifted shares for each region and each economic sector are applied to project the regional sector-specific employment based on the employment projections at national level. It is considered that regional competitive advantages once gained can disappear again in especially in the long-term. The "competitive (dis-)advantage factors" will gradually decrease over time by applying a convergence factor of 0.95.

```
For c = 2 To UBound(emplr_m(t), 2)
  For r = 2 To Ubound(emplr_m(t), 1)
    emplr_m(t)(r, c) = emplr_m(t – 1)(r, c) *
                       ((1 + (0.95 ^ (t – emplr_m_lastData)* (eass_m(t)(r, c) - 1)))
                       * (empl_v(t)(c - 1) /empl_v(t - 1)(c - 1)))
  Next
Next
```

Value added by economic sectors *varn_m(r,c)* is projected by applying the regional sector-specific labor productivity *lpr_m(r,c)* to regional employment by sectors *emplr_m(r,c)*. Usually, labor productivity is determined as the ratio of real production and employment. However, production by economic sectors is not available for all sectors and regions. Thus, labor productivity is calculated as the ratio of value added and employment.

Sectoral labor productivity at subnational level will develop as the respective sectoral labor productivity at national level. Then, regional value added by economic sectors can be projected by multiplying the regional sector-specific labor productivity and regional employment by economic sectors.

```
For r = 2 To UBound(lpr_m(t), 1)
  For c = 2 To UBound(lpr_m(t), 2)
    varn_m(t)(r, c) = lpr_m(t)(r, c) / 1000 * emplr_m(t)(r, c)
  Next
Next
```

Finally, **gross regional product** in nominal values *grpn_v(r)* is determined by assuming that gross regional product grows as total value added by region. Real gross regional product *grpr_v(r)* is determined by adjusting the nominal gross domestic product by the national GDP deflator *gdpd_v(12)*.

```
'Nominal GRP
For r = 2 To UBound(grpn_v(t))
  grpn_v(t)(r) = grpn_v(t - 1)(r) * varn_m(t)(r, 1) / varn_m(t - 1)(r, 1)
Next

'Real GRP
For r = 1 To UBound(grpn_v(t), 1)
  grpr_v(t)(r) = grpn_v(t)(r) / gdpd_v(t)(12) * 100
End If
```

For all regional economic indicators, the national values are determined by aggregation across all regions.

3.4 Energy module

3.4.1 General overview

The energy module describes the relations within the energy sector in greater detail than the economic model. It depicts the energy demand, supply and transformation by different fossil fuels and renewables as stated in the energy balance (see Table 4).

Table 4: Represented energy sources

Primary energy sources		Secondary energy sources
Fossil fuels	Renewable energy	
Coal	Biofuels and waste	Electricity
Crude oil	Hydro	Heat
Natural gas	Geothermal, solar etc.	Oil products

Source: Own illustration

The energy demand is mapped in detail for the largest consumers in the industry sector, for private households and the transport sector (Figure 28). Key drivers of sector-specific energy demand are the economic development of the sectors, the respective energy intensity of the production processes and the energy price development. The energy demand of private households is estimated with population.

The energy supply is determined by the energy demand of all sectors. Energy is either produced domestically or imported. Primary energy inputs for power generation as well as heat generation are captured.

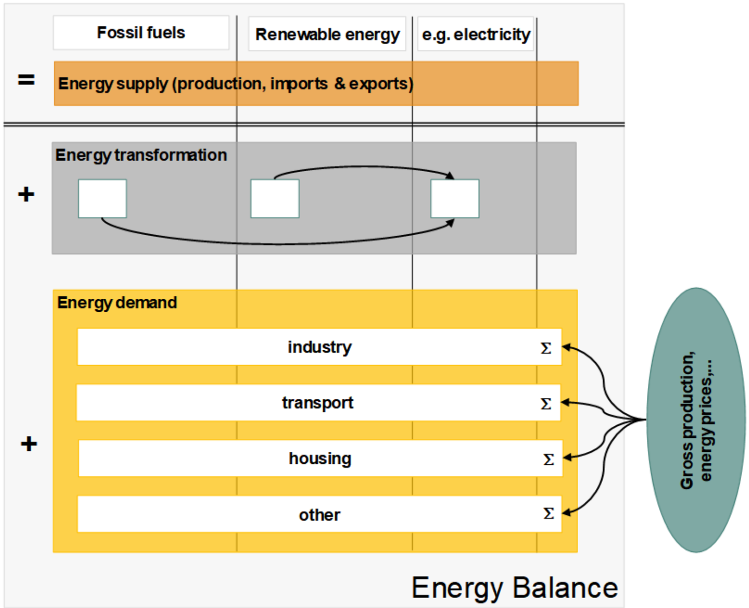


Figure 28: Energy module at a glance

Source: Own illustration

World market prices follow the projections of the World Bank, the International Energy Agency (IEA) and TIMES-KZ forecasts which affects the export price of crude oil extracted in Kazakhstan (World Bank 2020, IEA 2019). Energy prices to be paid for energy consumption by households and industrial consumers follow either domestic producer prices or world market prices.

3.4.2 Data set

The energy module is based on the following data set which is published by COMSTAT, IEA and the World Bank. Zhasyl Damu has compiled the energy price data by energy carriers for households and industrial consumers.

Table 5: Data set for the energy module

Energy Data		
Energy balance	Available from 1990-2023	COMSTAT (and IEA)
Energy prices	World market prices (1990-2023) Prices for households and industrial consumers for different fossil fuels (until 2023)	World Bank COMSTAT (Zhasyl Damu)

Source: Own illustration

3.4.3 Implementation into DIOM-X

In the energy module, both the energy prices and energy quantities (demand and supply) are projected given the relationships described in the subsequent paragraphs.

The **price of energy carriers** traded on the global market is determined by corresponding world market prices *wmp_v(r)*[17]. These follow the projections of the World Bank (until 2030), IEA (until 2040) and afterwards the projections of the TIMES-KZ model which is used in the "Green Economy" project. This exogenous data is set in the *Scenario* worksheet and enters the model via the tweak mechanism:

```
Tweak t, wmp_v_lastData, wmp_v, "wmp_v"
```

Energy prices to be paid by households and industrial consumers for energy consumption *ep_v(r)*[18] are estimated with domestic producer prices *gobpid_v(r)* instead of world market prices because most of the energy is produced in Kazakhstan.

Furthermore, sectoral average energy price indices *epi_v(r)* are calculated which determines – besides other relevant factors – the demand for energy. The energy price of each energy carrier is weighted by the energy use of the respective sector. For example, the higher the share of coal use in a sector, the more dominant is the impact of the coal price for this sector.

The modelling of **energy quantities** is determined by the structure of the Kazakh energy balance which shows the relationships between energy supply, energy transformation and energy demand for various fossil fuels and renewable energy sources in 1,000 tons of oil equivalents (ktoe). Figure 29 provides an overview of the approaches used to project the elements of the energy balance.

The driver of the sector-specific total energy demand in the industry, transport, commerce and public services sector as well as agriculture and forestry is the economic development of the sectors (as projected by the economic model, cf. section 3.2) *gobpir19_v(r)*[19] and, if appropriate, relative prices. The latter is the ratio of the sectoral average energy price index *epi_v(r)* and sectoral output prices *gobpid19_v(r)* indicating the ability to pass on energy costs to output prices. While a positive sectoral economic development increases the energy demand, an increasing relative price affects it negatively.

The modelling of the energy demand of private households *eb_m(36)(10)* is implemented in a simplified way and is modelled as a function of demographic development *pag_v(1)*. Past improvements in the energy efficiency is captured in the regression coefficient.

[17] See
Appendix 11.
[18] See
Appendix 12.
[19] Real output is transferred from 72 to 19 economic sectors as given in the energy balance. Mapping follows the instructions in Appendix 16.

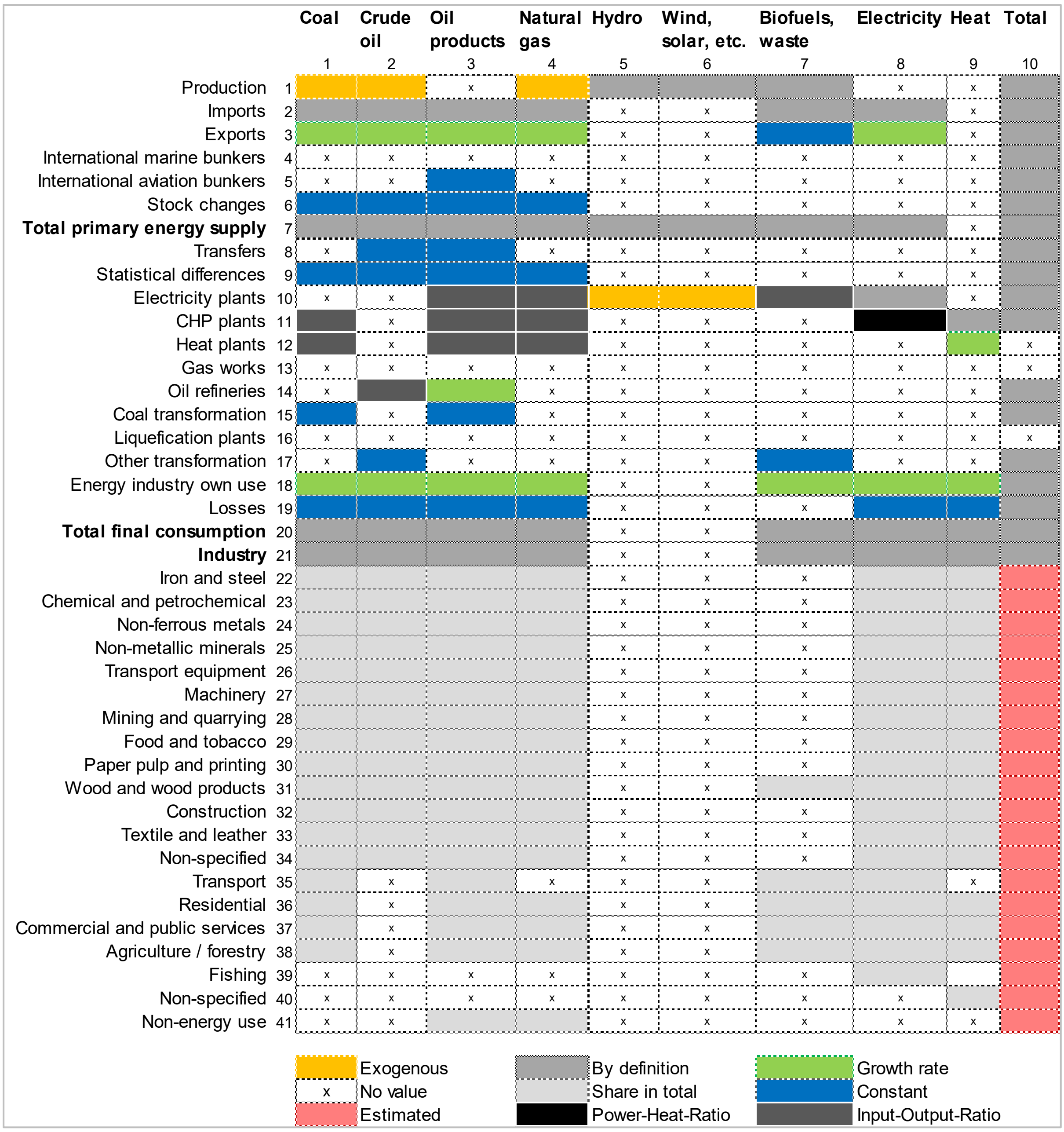


Figure 29: Approaches for projecting the elements of the energy balance

Source: Own illustration based on the IEA

The direction and magnitude of the relationship between the relevant variables is derived by applying econometric methods. The resulting regression equations for all sectors are included in the VBA code.

```
Public Sub EnergyDemand(ByVal t As Integer, ByVal iteration As Integer)
  ' Iron and steel
  If t > eb_m_lastData Then
    CHECK (gobpir19_v(t)(1) > 0 )
    eb_m(t)(22, 10) = exp(0.603 * Log(gobpir19_v(t)(1)) - 0.502 * dv_v(t)(52)
                                  - 0.010)
    End If
  End If
  ...
End Sub
```

The total energy demand of an industry (starting in row 22 of the matrix *eb_m*, cf. Figure 29 or Table 6) then determines the growth of final energy demand for each energy source (given in the columns *c* of the matrix) according to their historical shares *ebs_m(r)(c)* in total sectoral energy consumption. Mitigation strategies which increase the use of renewable energy in the sectors are given exogenously by applying the tweak mechanism.

```
If t <= eb_m_lastData Then
  For c = 1 To UBound(eb_m(t), 2)
    For r = 22 To UBound(eb_m(t), 1)
      ebs_m(t)(r, c) = eb_m(t)(r, c) / eb_m(t)(r, 10)
    Next
  Next
End if

Tweak t, ebs_m_lastData, ebs_m, "ebs_m"

If t > eb_m_lastData Then
  For r = 22 To UBound(eb_m(t), 1)
    For c = 1 To UBound(eb_m(t), 2)
      eb_m(t)(r, c) = eb_m(t)(r, 10) * ebs_m(t)(r, c)
     Next
  Next
End if
```

Total final consumption (TFC) for each energy source *eb_m(20, c)* respectively is the sum of the final energy demand over all energy consumers (Table 6).

Table 6: Total final consumption

21	Industry	35	Transport
22	Iron and steel	36	Residential
23	Chemical and petrochemical	37	Commercial and public services

24	Non-ferrous metals	38	Agriculture / forestry
25	Non-metallic minerals	39	Fishing
26	Transport equipment	41	Non-specified
27	Machinery		
28	Mining and quarrying		
29	Food and tobacco		
30	Paper pulp and printing		
31	Wood and wood products		
32	Construction		
33	Textile and leather		
34	Non-specified		

Source: Own illustration

Since primary energy (e. g. crude oil) is usually not provided directly to the consumer, the energy module contains the transformation sector, which converts domestic and imported (primary) energy to final energy (heat and electricity, oil products).

Total final energy consumption determines, in principle, the energy transformation out-put. Thus, , it is assumed that transformation output of oil refineries *eb_m(14, 3)* and final energy consumption of oil products *eb_m(20, 3)* are directly proportional to each other.

```
eb_m(t)(14, 3) = eb_m(t - 1)(14, 3) * eb_m(t)(20, 3) / eb_m(t - 1)(20, 3)
```

According to the energy balance, heat plants producing only heat are using coal and gas. The heat output of heat plants *eb_m(12, 9)* is determined by total final heat consumption *eb_m(20, 9)* as well as the energy industry's own use of heat *eb_m(18, 9)* and heat losses *eb_m(19, 9)*.

Additionally, combined heat and power (CHP) plants cogenerate heat and power which is demanded for by final energy consumers. The historically observed "efficiency factor" showing the ratio of the electricity and heat generation is used to derive the electricity output of CHP plants *eb_m(11, 8)*.Electricity plants generate electricity using natural gas, oil products or renewable energy sources such as wind, solar PV and hydro. The "green" power supply is dependent on the deployment of renewable energy (e. g. hydro *eb_m(10, 5)* or wind / solar *eb_m(10, 6)*) which can be forced through regulation or legislation (e. g. "Green Economy" strategy). This has to be set in scenarios. If the demand for electricity cannot be fully met by renewable energies, the remaining electricity is generated in fossil-fueled power plants (mainly gas).

```
Tweak t, eb_m_lastData, eb_m, "eb_m"
```

After determining the energy output in the energy transformation sector (e. g. heat and oil products), the input of fossil fuels, renewable energy and other fuels for generating the output are calculated assuming that the most recent relation of energy input and energy output is constant. These "efficiency factors" (*ebs_m(t)(11, c) for CHP plants, ebs_m(t)(12, c) for heat plants and ebs_m(t)(14, c)* for oil refineries) for the energy conversion plants can be adjusted in scenarios.

```
For c = 1 To UBound(eb_m(t), 2)
  eb_m(t)(11, c) = ebs_m(t)(11, c) * (eb_m(t)(11, 8) + eb_m(t)(11, 9))
  eb_m(t)(12, c) = ebs_m(t)(12, c) * eb_m(t)(12, 9)
  eb_m(t)(14, c) = ebs_m(t)(14, c) * eb_m(t)(14, 3)
Next
```

Transfers and statistical differences, are assumed to be constant. Expert knowledge might be used to relax this strict assumption. Energy industry own use develops with the energy generated in this sector.

Total primary energy supply (TPES) *eb_m(7, c)* can, by definition, be calculated either from a supply or demand perspective. The underlying approach follows the latter.

Table 7: Determination of total primary energy supply

Supply perspective

	Production
+	Imports
-	Exports
-	International marine bunkers
-	International aviation bunkers
+	Stock changes
=	**Total Primary Energy Supply**

Demand perspective

	Energy transformation input
-	Energy transformation output
+	Energy industry own use
+	Losses
+	Total final consumption
=	**Total Primary Energy Supply**

Source: Own illustration

Next, remaining components on the supply side are determined. Primary energy is predominantly mined in Kazakhstan, a little is imported. A part of domestic production is exported.

Domestic production *eb_m(1, c)* for fossil fuels and biofuels are exogenously given (here based on the TIMES-KZ model projections). For other renewable energy sources domestic production equals by definition TPES.

Energy exports by energy carriers *eb_m(3, c)* grow at the same rate as the respective exports by products in the economic model *totfdn_m(r, 9)* considering respective world market prices *wmp_v(r)* and the exchange rate *exra_s*.

```
'coal
eb_m(t)(3, 1) = eb_m(t - 1)(3, 1)*(totfdn_m(t)(4, 9)/(wmp_v(t)(2) * exra_s(t))) /
                          (totfdn_m(t - 1)(4, 9) / (wmp_v(t - 1)(2) * exra_s(t - 1)))
'crude oil
eb_m(t)(3, 2) = eb_m(t - 1)(3, 2)*(totfdn_m(t)(5, 9)/(wmp_v(t)(1) * exra_s(t))) /
                           (totfdn_m(t - 1)(5, 9) / (wmp_v(t - 1)(1) * exra_s(t - 1)))
...
```

International marine and aviation bunkers as well as stock changes are assumed to be constant. Thus, imports *eb_m(2, c)* can be calculated as residuals.

3.5 Emission Module

3.5.1 General overview

The emission module records the energy-related CO_2 emissions[20] in the energy industry, manufacturing and construction as well as transport and other sectors such as commercial and residential sector. Reductions in the use of fossil fuels caused by deployment of renewable energy or increased energy efficiency can be seen in CO_2 savings. In contrast to the energy module, this module has only reporting characteristics and does not contain feed-back effects into the economic model.

3.5.2 Data set

The data on CO_2 emissions (in 1,000 CO_2) and implied emission factors (in kt CO_2 / TJ), are provided by the GHG inventories from the United Nations Framework Convention on Climate Change (UNFCCC) from 1990 – 2021.

3.5.3 Implementation into DIOM-X

Basically, CO_2 emissions by sectors *co2e_v(r)* are calculated by multiplying the implied emission factors *ief_m(r, c)* and corresponding sectoral energy consumption of fossil fuels *eb_m(r, c)*.

First, a factor *ktoeToTJ* must be considered which converts ktoe into TJ. Second, the energy use of the economic sectors given in the UNFCCC and energy balances have to be allocated accordingly.

Due to the fact that energy consumption published in the UNFCCC and in the energy balances is not identical, historical CO_2 emissions cannot be reproduced by using the approach described above. Thus, to avoid a break in the time series of past and projected CO_2 emissions due to differences in underlying data sets, growth rates of the calculated CO_2 emissions are used to connect past and projected emissions.

```
For c = 1 To 4                        'fossil fuels
  For r = 10 To 12                    'energy industry
    If eb_m(t)(r, c) < 0 Then         'only energy input, which is negatively defined!
      co2e_prelim_v(t)(3) = co2e_prelim_v(t)(3) + Abs(eb_m(t)(r, c)) * ktoeToTJ *
                              ief_m(t)(1, c)
    End If
```

[20] Other GHG emissions (e. g. CH_4, N_2O) and other GHG source and sink categories (e. g. industrial processes and use, agriculture) are not considered in the model e3.kz. The covered CO_2 emissions amount to 94% of total net CO_2-emissions. Total CO_2-emissions sum up to 80 % of all GHG emissions.

```
  ...
  Next
Next
co2e_v(t)(3) = co2e_v(t - 1)(3) * co2e_prelim_v(t)(3) / co2e_prelim_v(t-1)(3)
```

Third, for projecting non combustion-related CO_2 emissions caused by fugitive emissions, a simplified approach is used: Fugitive emissions from solid fuels *co2e_v(t)(9)* are linked to coal transformation. Fugitive emissions from oil and natural gas *co2e_v(t)(10)* are assumed to grow with the same rate as the production of both.

```
'solid fuels: flaring of coke oven gas
co2e_v(t)(9) = co2e_v(t - 1)(9) * Abs(eb_m(t)(15, 1)) /
                    Abs(eb_m(t - 1)(15, 1))
'oil and gas
co2e_v(t)(10) = co2e_v(t - 1)(10) * (eb_m(t)(1, 2) + eb_m(t)(1, 4)) /
                    (eb_m(t - 1)(1, 2) + eb_m(t - 1)(1, 4)) 'oil+gas
```

4. SCENARIO OR "WHAT-IF" ANALYSIS

4.1 General remarks

Economists use scenario analysis as methodology for dealing with the uncertainties of the future. Scenarios are consistent sets of quantified assumptions describing the future development. A scenario helps to better understand what could happen, who / what is affected and how. Thus, a scenario should not be considered a precise forecast; instead it shows development paths that are reactions to the assumptions made ("what-if" analysis).

The starting point of such analysis usually is a reference scenario which relies on a set of exogenous assumptions (e. g. population forecasts) and historically observed behavior of economic actors which is assumed to continue in the future. For example, if consumers never reacted to price changes of certain goods, they will not react to it in the future (inelastic demand).

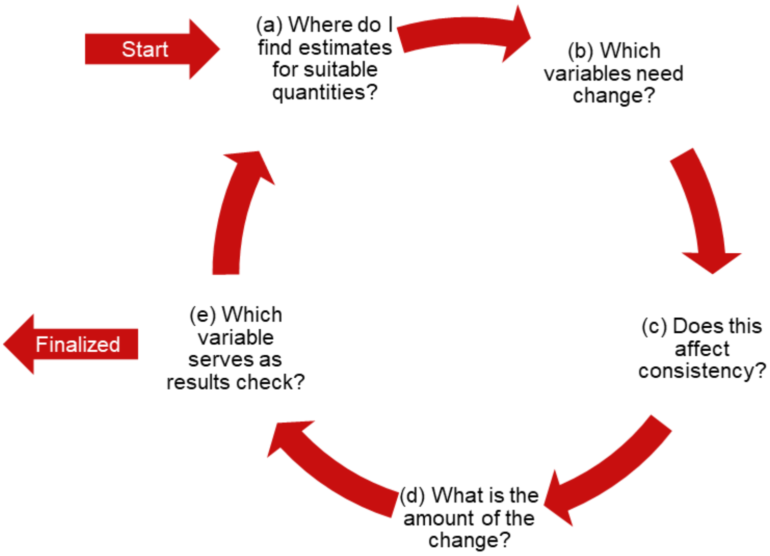


Figure 30: Scenario building

Source: Own illustration

Building a scenario is based on the steps shown in Figure 30. According to the underlying questions that should be answered, sources (literature, experts) for suitable quantities need to be identified (a). Then, appropriate model variable(s) need(s) to be selected (b). For this, knowledge about the model structure is required. Not every model variable can be adjusted or "tweaked", i. e. no left hand side variables of identities – otherwise the definition does not hold anymore. For example, GDP by definition equals consumption, investments and net exports. Thus, it should never be "tweaked". Instead, one of the GDP components (e. g. consumption) could be tweaked (c).

Basically, all model variables that are estimated, exogenously[21] given or not projected (assumed to be constant in the future) can be "tweaked". Exemplary variables are listed in the following table. In the worksheets *Dataset* and *RowColDesc* of the workbook e3kz.xlsb, a color code shows if certain model variables are tweakable (green), partially tweakable (orange) or not tweakable (red). *Partially tweakable* indicates that only some elements of a vector or a matrix variable can be tweaked.

Table 8: "Tweakable" model variables

E3.kz Model Variable	Description
pag_v	Population by age groups (exogenous)
exra_s	Exchange rate (exogenous)
impd_v	Imports, deflator (exogenous)
gdpd_v	GDP by final use, deflator (estimated)
gdpr_v	GDP by final use, constant prices (partly estimated)
empl_v	Employment by economic activities (estimated)
sna_v	System of National Accounts (partly estimated)
lf_s	Labor force (estimated)
wmp_v	World market prices (exogenous)
eb_m	Energy balance (partly estimated)
ebs_m	Energy balance (e.g. renewable energy shares; not projected)
ticr_m	Total input coefficients, real (not projected)
impfdn_m	Imported final/total demand components at basic prices (not projected)
totfdn_m	Total final/total demand components at basic prices (not projected)

Source: Own illustration

In a next step (d), the amount of change is given for the selected variable(s). Each assumption in a scenario needs to be quantified, carefully checked and evaluated with expert knowledge (e). The model cannot check the plausibility of an assumption. Implausible assumption yield implausible results and might even stop model execution prematurely if the model fails to converge.

Before **running the scenario**, the model user should have an idea which model variable(s) he / she expects to be impacted by the initial change / shock. Afterwards, **scenario evaluation** takes place.

Scenario building can be simple in terms of tweaking only one model variable (e. g. lower oil exports) but also quite complex if a scenario is based on a set of assumptions (e. g. climate change scenario, see example in section 4.2). It is recommended to build comprehensive scenarios step-by-step to first understand the effects of single assumptions. Otherwise, interpretation of scenario results gets quite difficult. Additionally, knowledge about the model structure is required to get a good understanding of the scenario results.

[21] At least all exogenous variables e. g. population *pag_v* must be" tweaked". Otherwise they will have the same value for the future as observed for the last year where historical data is available.

To see the effects of an alternative scenario, it must be compared to another (usually the reference[22]) scenario. Deviations for each model variable are given in % and / or absolute deviations in the underlying units e. g. monetary values or physical units (Figure 31). These deviations can be attributed to the different assumptions in the scenarios.

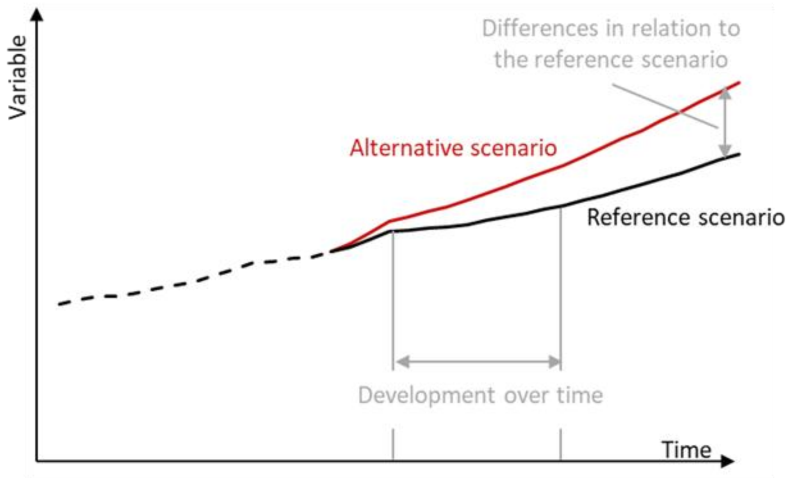


Figure 31: Scenario comparison

Source: Own illustration.

4.2 Climate change and adaptation scenarios

Integrating climate change into economic models is challenging. Usually, economists derive future developments from past observations. Unfortunately, economic impacts from climate change are not directly visible in time series data of economic models. Either climate change did not cause any observable damage to the economy, was not relevant for the economic performance or could not even be detected as an impact from climate change due to the fact that repairing climate change damages results in positive GDP effects (so called defensive spending). In addition, the damage may have been avoided or reduced by adaptation measures.

Furthermore, economic and climate models are operating on different temporal and spatial scales. While climate models have a high spatial resolution and a long-term horizon, e3.kz models the Kazakh economy at the national level and has a mid to long-term perspective (until 2050). Additionally, climate models are very computation intensive while the e3.kz model computes in less than a minute on an average desktop computer or laptop.

Thus, climate models are not integrated into e3.kz. Instead, scenario analysis is applied to model climate change and adaptation which follows a four-step approach:

[22] In the case of adaptation scenarios, they must be compared to a scenario including the respective climate change event (for more see section 4.2).

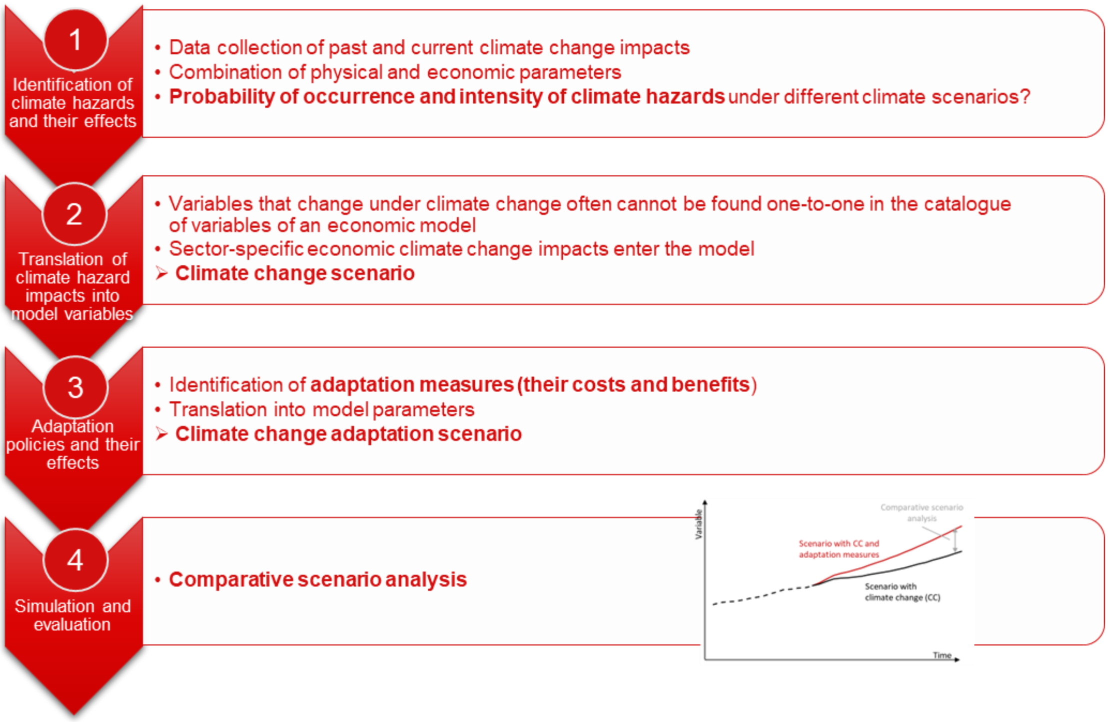


Figure 32: Four-step approach to implement climate change and adaptation in an economic model

Source: Own illustration.

Following this approach helps to understand the macroeconomic impacts of climate change and how potential adaptation measures help to minimize or even avoid these effects.

(1.) A scenario with climate change is created which explicitly implements climate hazards and its effects. The probability of occurrences and the intensity of country-specific climate hazards (droughts, heatwaves and floods) are provided for three Shared Socio-economic Pathways (SSP)[23] (SSP1-2.6, SSP2-4.5 and SSP5-8.5) scenarios (see section 4.2.1) by experts from Earthyield Advisories applying climate models with a focus on Kazakhstan (GIZ 2025a).

The impact chain concept (Fritzsche et al. 2014) is used to identify relevant interfaces and effect chains (e. g. a drought may impact agricultural production and power generation). The aim is to derive and link biophysical and economic effects of a climate hazard (e. g. water scarcity affects agricultural output). In particular, sector-specific damage resp. impact data from past climate events are used to identify and value the direct climate change impacts. These are collected by screening of scientific (national and international) literature, media and expert surveys ("bottom-up" approach). The damage / impact data (see section 4.2.1) differentiated for three intensity categories (low, medium and high), if possible, serves as a benchmark for estimating future climate hazard impacts. Adjustments will be made to the benchmarks in scenarios to reflect the expected probability of occurrences of climate hazards by assuming that, for example, the doubling of the probability of occurrences per year will also double the benchmark impacts. The combination

[23] The SSPs represent different climate policy choices at global scale impacting GHG emissions pathways. SSP58.5 (SSP1-1.9) is the most pessimistic (optimistic) scenario assuming stronger (weaker) climate warming effects due to higher GHG emissions compared to the preindustrial level. (see e.g. climateknowledgeportal.worldbank.org/overview)

of the future evolution of climate hazards by intensities and observed climate hazard impacts by intensity category results in a time series of expected future impacts for the respective climate hazards.

If time series with damage / impact data are provided by literature and / or experts, they can be taken over directly as in the case of output losses in agriculture (UNDP 2020).

(2.) The identified climate change effects need to be translated into model parameters. The structure of the e3.kz model may require translations. For example, some variables in the model cannot be directly tweaked because they are given by definition. Changes in production are implemented in e3.kz by adjusting either demand or imports. Basically, the initial impacts of climate events are implemented as effects on human behavior, production factors and / or infrastructure (indicated by ● in Figure 33), e. g.

- Household consumption expenditures by various products,
- Exports by various products,
- Investments goods,
- Imports by various products,
- Employment in various economic sectors,
- Prices for various products,
- Intermediate demand and
- Lower output from (hydro) power generation.

and cause chain reactions within the E3 modelling system. The resulting impacts for other economic sectors not directly impacted by climate change as well as macroeconomic effects can then be evaluated by comparing the respective climate change scenario with a hypothetical no- climate change scenario (reference scenario). Section 4.2.2 shows how the impacts of a climate hazards are implemented in the e3.kz model, using the example of a drought. Section 4.2.4 gives examples how to evaluate the impacts.

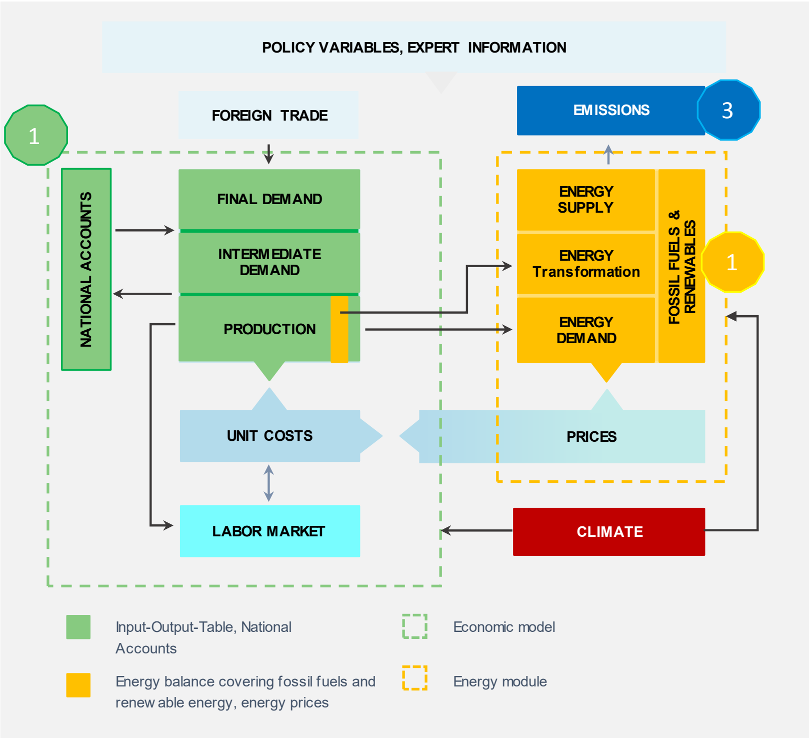


Figure 33: Implementing climate change damages into e3.kz

Source: Own illustration

(3.) Possible adaptation measures are identified to prevent or minimize the damages or taking advantage of the opportunities that may arise. These measures are identified by screening national and international literature as well as discussions with Kazakh experts. Costs and benefits (in terms of damage reduction) of possible measures need to be monetarized and then fed into the e3.kz model. While the benefits are implemented into e3.kz as the reverse impacts of climate change damages, costs are usually integrated as investments of various products, e. g. irrigation systems.

(4.) For evaluating the impacts of adaptation measures, the climate change scenario and the adaptation scenario must be compared. Usually, there is more than one adaptation option (e. g. irrigation systems or drought-resistant crops). The model helps to identify the option(s) with high effectiveness and positive effects on the economy and the environment. Selection criteria might be the biggest avoided damages, employment effects or synergies with other strategies such as mitigation which needs to be prioritized by policymakers.

4.2.1 Data sets

The data needed to implement the impacts of climate hazards into an economic model comprises both the *probability of occurrences of a climate hazard indicator* by intensity in Kazakhstan and *sector-specific economic impacts* differentiated for three intensity categories from past climate hazards. The combination of both data sets enables the creation of a time series on future climate impacts ("bottom-up" approach).

Other options are, if available, to rely on country-specific forecasts from top-down models (e. g. projections of labor productivity losses during heatwaves from Climate Analytics[24]) or bottom-up resp. sector models (e. g. yield forecasts from agriculture models, see UNDP 2020) developed under different climate scenarios.

The implementation of adaptation measures requires costs and benefits (in terms of damage reduction) of each measure. As with data on climate hazard impacts, ideally the information are country-specific and can be derived from past experiences or from undertaken *sector-specific cost-benefit analyses* (CBAs). Otherwise, knowledge from international experiences may be adopted for a first estimate but must be verified by local sector-experts. The available data and information for possible adaptation measures are not described in the e3.kz model handbook but in the national report (GIZ 2025c) and policy briefs for key sectors such as *agriculture* and *energy* (Großmann et al. 2021) and other forthcoming publications jointly created with Berlin Economics and Kazakh experts.

Climate hazard indicators

In course of the CRED II project, the focus is on three hazards (droughts, heatwaves and floods). Earthyield Advisories provide time series data of probability of occurrences by intensity category for those hazard indicators under three climate scenarios SSP1-2.6, SSP2-4.5 and SSP5-8.5 (Table 9). The results of their analyses on a resolution of 110 km x 110 km with a climate model part of Coupled Model Intercomparison Projects (CMIP6) are then aggregated to implement the data into the e3.kz model. A detailed description

[24] https://climate-impact-explorer.climateanalytics.org/impacts/?region=KAZ&indicator=ec1&scenario=rcp85&warmingLevel=3.0&temporalAveraging=annual&spatialWeighting=area&altScenario=rcp26&compareYear=2030

of the definition and estimation of climate hazard indicators is described in the report by Earthyield Advisories (2025a).

Table 9: Probability of occurrences by climate hazard and intensity category for SSP1-2.6, SSP2-4.5 and SSP5-8.5, 2024-2050 (excerpt)

		Definition		Baseline (1981-2010)	2024	2025	2026	...	2049	2050
	Low	SPEI < -1		0,32	0,38	0,37	0,37		0,37	0,37
SSP1-2.6	Medium	SPEI < 1.5	Drought	0,15	0,21	0,21	0,20		0,21	0,21
	High	SPEI < -2		0,03	0,06	0,06	0,05		0,07	0,07
	Low	SPEI < -1		0,32	0,36	0,36	0,37		0,38	0,38
SSP2-4.5	Medium	SPEI < 1.5	Drought	0,15	0,21	0,21	0,21		0,23	0,23
	High	SPEI < -2		0,03	0,05	0,05	0,05		0,07	0,07
	Low	SPEI < -1		0,32	0,38	0,38	0,38		0,38	0,38
SSP5-8.5	Medium	SPEI < 1.5	Drought	0,15	0,23	0,23	0,22		0,24	0,24
	High	SPEI < -2		0,03	0,07	0,07	0,07		0,08	0,08
	Low	Duration > 5 days		0,11	0,19	0,17	0,21		0,42	0,42
SSP1-2.6	Medium	Duration > 8 days	Heat Wave	0,02	0,02	0,02	0,07		0,15	0,13
	High	Duration > 10 days		0,00	0,00	0,00	0,02		0,05	0,02
	Low	Duration > 5 days		0,11	0,18	0,18	0,24		0,43	0,46
SSP2-4.5	Medium	Duration > 8 days	Heat Wave	0,02	0,03	0,03	0,06		0,13	0,13
	High	Duration > 10 days		0,00	0,01	0,01	0,01		0,04	0,05
	Low	Duration > 5 days		0,11	0,38	0,40	0,38		0,45	0,46
SSP5-8.5	Medium	Duration > 8 days	Heat Wave	0,02	0,06	0,06	0,06		0,16	0,17
	High	Duration > 10 days		0,00	0,01	0,01	0,01		0,07	0,07
	Low	Risk score > 80th percentile		0,20	0,33	0,44	0,49		0,41	0,42
SSP1-2.6	Medium	Risk score > 90th percentile	Flood	0,10	0,15	0,21	0,29		0,21	0,21
	High	Risk score > 98th percentile		0,02	0,02	0,02	0,03		0,04	0,03
	Low	Risk score > 80th percentile		0,20	0,48	0,46	0,43		0,48	0,48
SSP2-4.5	Medium	Risk score > 90th percentile	Flood	0,10	0,25	0,25	0,25		0,24	0,24
	High	Risk score > 98th percentile		0,02	0,04	0,04	0,04		0,03	0,02
	Low	Risk score > 80th percentile		0,20	0,28	0,33	0,39		0,61	0,64
SSP5-8.5	Medium	Risk score > 90th percentile	Flood	0,10	0,13	0,15	0,19		0,40	0,45
	High	Risk score > 98th percentile		0,02	0,02	0,03	0,03		0,09	0,09

Source: GIZ 2025a

Sector-specific economic climate change **impacts**

Different sources are used to collect detailed, quantified and monetarized data ("bottom-up approach") on past climate change impacts. Main data providers and sources, amongst others, are:

- Kazhydromet
- Committee of Emergency Situations of the Ministry of Internal Affairs
- Ministry of National Economy (2018): Kazakhstan in 2019. Statistical yearbook (https://stat.gov.kz/edition/publication/collection)
- World Bank (2016): Kazakhstan – Agricultural sector risk assessment. (https://documents1.worldbank.org/curated/en/422491467991944802/pdf/103076-WP-KZ-P154004-Box394863B-PUBLIC-ASRA.pdf)

- OECD (2019): Risk Governance Scan of Kazakhstan (https://read.oecd-ilibrary.org/governance/risk-governance-scan-of-kazakhstan_cb82cae9-en#page4)
- Ministry of Environment and Water Resources, UNDP, GEF (2013): The Third-Sixth National Communication of the Republic of Kazakhstan to the UNFCCC.
- Ministry of Energy, UNDP, GEF (2017): 7th National Communication and 3rd biennial report of the Republic of Kazakhstan to the UNFCCCC

Furthermore, reports in newspapers and online articles were screened. The results of the collection – which has been updated by a national consultant in 2024 – are summarized in a MS Excel table. Important to note is that not all damages from climate hazards are reported, i. e. not monetarized. Table 10 and Table 11 show the reported non-monetary and monetary damages by climate hazards observed in Kazakhstan at a glance. Directly impacted form climate change are mainly the agriculture, forestry, construction, water, transport, energy and industry sector. The largest known monetary damages were caused by extreme precipitation, floods and droughts. While Table 10 depicts sector-specific damages, the monetary damages in Table 11 show the totals. For analyzing the inter-industry effects and to derive sound impacts for the macro-economy, sector-specific impacts are very important. Otherwise, sector-specific labor-intensities and import dependencies cannot be considered. Thus, further evidence and expert knowledge should be consulted.

Apart from observed historical damages for different climate events (as given in Table 11), there are also sector-specific models which forecast climate change impacts under different climate scenarios (e. g. the dynamic model of crop yield formation, MNE et al. 2017, UNDP 2020). The quantified results of these models may also serve as input for the e3.kz model.

Table 10: Reported non-monetary damages

Economic sectors affected	Extreme precipitation, floods, landslide, mudflows	Extreme Wind	Drought	Wildfire
Agriculture	Damaged crops		Damaged crops	
	Damaged agricultural lands			
	Killed livestock			
Forestry	Damaged logs	Knocked down trees		Burned forestry
Construction	Damaged buildings	Damaged roofs		
	Damaged bridges			
	Destroyed dams			
Industry	Flooded economic objects			
Energy	Damage to electricity supply	Damage to power lines, gas pipelines	Hydro power plants affected	
Water	Damaged pipes			
	Destroyed sewer network and water supply			
ICT	Damage to communication infrastructure	Damage to communication infrastructure		
Transport	Blocked road and train traffic	Blocked road and train traffic		

	Damages roads			
	Damaged cars	Damaged cars		

Source: Own illustration based on Data compilation by Kazhydromet, Aibat Muzbay, GWS.

Table 11: Selection of reported monetary damages in Mln. KZT

Year	Snow melt / Floods*	Extreme precipitation** / rainfall flood	Landslide, mudflows, slope washout	Extreme Wind***	Drought	Wildfire
1991	3	3		0.2		15
1992	0.2					
1993	5	67 - **30,000**	9	13		
1994	873	72	88	3	n.a.	281
1995	382 + 5[1]	1,230	34	144	n.a.	260
1996	55 + 21[2]	374	43	81	n.a.	37
1997	291	153		93	n.a.	128
1998	863	3,165	3	**732**	75,000	36
1999	200	16	62	19		29
2000	195	10		18	n.a.	13
2001	40			3		10
2002	504	22		10		50
2003	113		11	209		6
2004	5			129		22
2005	35			99		21
2006				0.5		387
2007	4	4		3		**502**
2008	**15,284**			**900**	n.a.	**581**
2009				21		91
2010	**5,400**			11	17,000	332
2011	**9,782**					5
2012	440–1,192				153,000	532
2013	4		464			332
2014	1,185–2,974			2,500	140	77
2015	17,600–19,600			501		119

2016	60-811			29		29
2017		4,771		511		216
2018	1,095			57		210
2019	515			37		564
2020				24		532
Total	64,846-100,071		714	6,148	245,140	5,417

* including groundwater level rise[1], sea level fluctiation[2]

** including heavy snowfall

*** including blizzards, wind surge, dust storm, snowstorm, whirlwind, squall wind

Source: Data compilation by Kazhydromet, Aibat Muzbay, GWS.

To complement the "bottom-up" approach, which cannot be considered a complete and systematic collection of data, other studies analyzing the macroeconomic and sectoral impacts of climate hazards in Kazakhstan are reviewed ("top-down" approach). This provides (1) additional data of climate impacts in Kazakhstan, (2) helps to scale up "bottom-up" data, if not sufficient and (3) enables to compare own scenario results. For example, the World Bank (2022), IMF (2019) and Waidelich et al. (2024) publish GDP per capita losses for different SSP scenarios.

4.2.2 Implementation of scenarios

Scenario assumptions are usually defined in the *Scenario* worksheet of the workbook *e3kz.xlsb*. Some assumptions require auxiliary calculations which cannot be easily implemented there. Such calculations should be done in separate files / worksheets (workbook *"ScenarioInput.xlsx")* to keep the model clean and lean. The final results of these calculations are then integrated into the *Scenario* worksheet.

Most scenarios can be implemented directly in the *Scenario* worksheet. In that case, the description of how to create the tweak inputs in the workbook *ScenarioInput.xlsx* can be skipped. Climate change scenarios are more complex, thus tweak inputs are created in *ScenarioInput.xlsx*.

How to create the tweak inputs in the workbook *ScenarioInput.xlsx?*

Figure 34 shows the structure of the *ScenarioInput.xlsx* workbook. There is a worksheet *SSP_SELECTION*, a worksheet *ClimateHazards_SSP* and three worksheets for each climate hazard under consideration. These three sheets have a color code (e. g. yellow for droughts), which is also used in the *Scenario* worksheet to identify the set of assumptions more easily.

- *SSP_Selection* allows the user to select one of the three RCP scenarios.
- *ClimateHazards_SSP* includes for each SSP scenario the probability of occurrences for each climate hazard by intensity category until 2050 (see also Table 9).
- Worksheet *Drought* etc. includes the set of assumptions for the climate hazard and adaptation scenarios to be defined by the scenario builder.

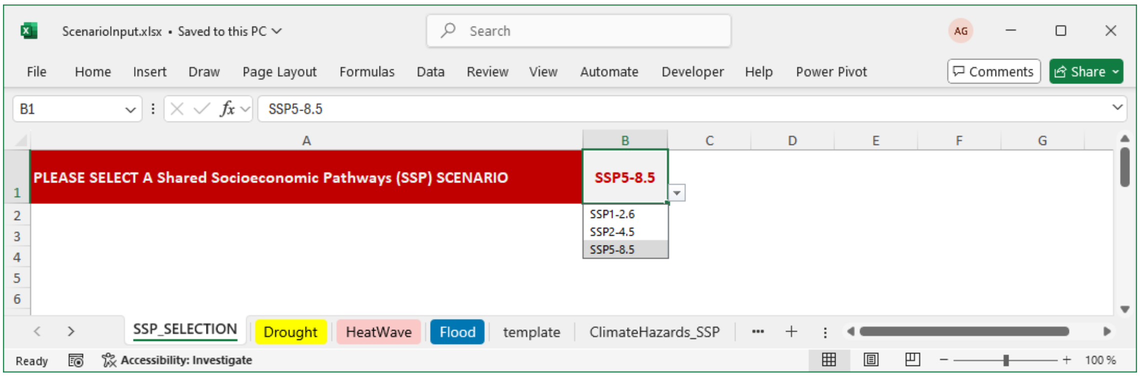


Figure 34: Workbook "ScenarioInput.xlsx"

Source: Own illustration.

Each of the three worksheets considering climate hazards has the same structure (Figure 35). The first four *columns* (A to D) look exactly as the ones in the *Scenario* worksheet where the model variable, its row and column indices and the applied tweak type need to be specified. The next column E is a placeholder for the tweak descriptions. Column F (to H) includes the assumptions to be applied in the simulation period until 2050.

In row four to six, the probability of occurrences by intensity category of the respective climate hazard is linked to the worksheet *ClimateHazard_SSP*. Depending on which SSP scenario is selected (see worksheet *SSP_SELECTION*), the appropriate data is displayed.

Starting with row eight, the climate impacts are quantified. The number of rows depends on the specified climate impacts and can be extended by inserting additional rows.

In this example, from row 13 onwards the assumptions on costs and benefits of adaptation measures are set. Again, additional rows can be integrated for more assumptions on adaptation measures. In column H, the model user can adjust the benefit from a CBA to reflect a larger or smaller benefit for the same adaptation investment under different SSP scenarios. For example, if the height of a dam is suitable to prevent flooding in a less severe climate scenario, the level of protection may not be sufficient in a more severe climate scenario.

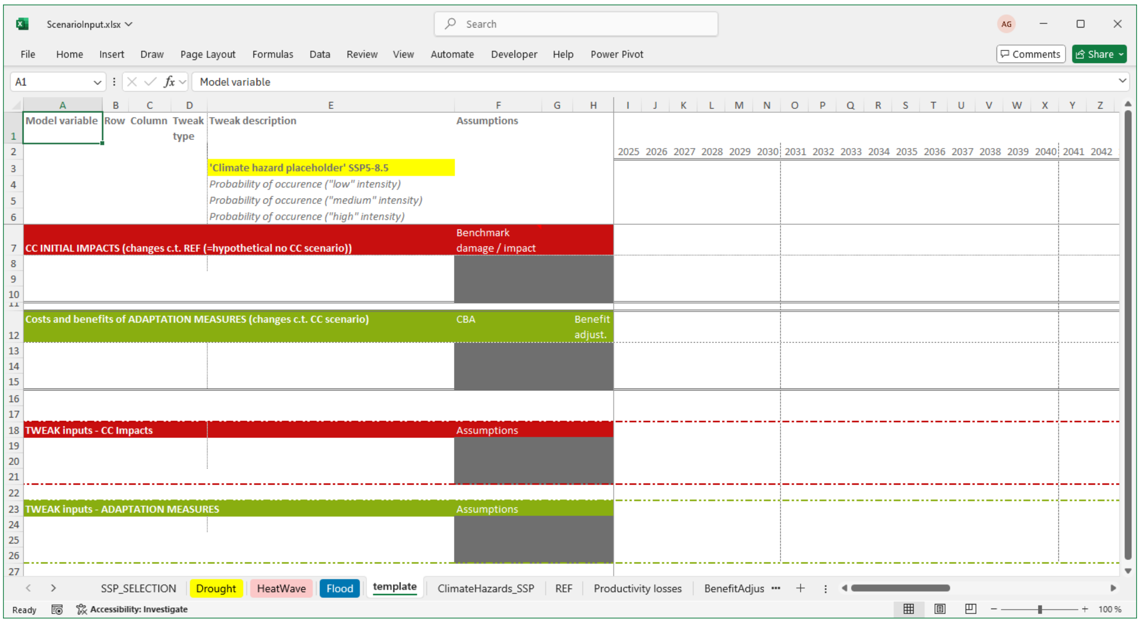
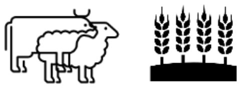
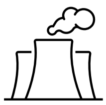
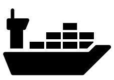


Figure 35: Template for scenario inputs of climate hazard impacts and costs and benefits of adaptation measures

Source: Own illustration.

Taking the example of a drought, the following effects on economic sectors are observed in Kazakhstan (cf. section 4.2.1) or known from drought events occurred in other countries:

Table 12: Exemplary impacts of a drought

Sector	Drought impacts	Sources
	Yield losses in agriculture (7 to 300 Bn. KZT)	Collection of past and current climate impacts in Kazakhstan
	Decreased hydro power production due to lower water levels (-5.2% to -20%)	International study (van Vliet et al. 2016), IEA energy balance 1998
	Reduced thermoelectric power potential due to insufficient cooling (-3.8% to -4.7%)	International study (van Vliet et al. 2016)
	Increased water demand in water-intensive sectors, e.g. agriculture	Own assumption based on historical data
	Impaired water transport causes increasing costs	Own assumption based on historical data

Source: Own illustration.

The climate hazard impacts should be differentiated for the three climate hazard intensity categories (low, medium and high) assuming that a low (high) intensity event causes the smaller (greater) damage / impact.

Some assumptions can be easily linked to e3.kz model variables, e. g. decreased hydro power production in the energy sector which is the model variable *eb_m(10,5)*. Other assumptions require additional calculations, e. g. wheat yield losses in agriculture. Output cannot be tweaked because it is a result of the demand-driven model e3.kz. Thus, the scenario builder has to tweak the demand and / or imports of "Agriculture, hunting products and related services" instead of the output.

The final tweak inputs (framed with a dot-dash line) are given starting in row 19 (cf. Figure 35). These tweaks then are linked (or copied and pasted) to the *Scenario* worksheet in the *e3kz.xlsb* workbook.

At the example of a drought event, the steps to implement the scenario are described subsequently and follow the general scenario building procedure (cf. section 4 and 4.2).

First, the SSP5-8.5 scenario, for example, is selected in worksheet *SSP_SELECTION*. Second, the average benchmark impacts by intensity category in agriculture, energy, water and transport sector are given in column F (cf. Table 12).

In this example, the impacts in the agriculture sector, hydro power generation *eb_m(10, 5)* and energy supply from thermoelectric plants *tv_chpe_s* and some others are considered as impacts from droughts. The historical benchmark impacts by intensity category are multiplied by the probability of occurrences for each climate hazard and intensity category. This step assures that an increasing probability of occurrences is reflected in the future damages. If the benchmark impact is given in percent, it must be multiplied with the respective value of the model variable (from the reference scenario) to calculate the impact in the respective unit of this model variable. Afterwards, the impact can be added to receive the total impact.

Then, for example the agricultural loss must be translated into tweakable model variable(s) (Figure 36 row 94 to 95). Two options are available. On the one hand, agricultural exports *totfdn_m(1, 9)* can be tweaked assuming that the drought results in foregone export chances. On the other hand, the demand for agricultural products on the domestic market needs to be compensated by higher imports *impfdn_m(1, 1)*. In this example, it is assumed that twelve percent of the loss in agriculture result in lower exports and 84 %[25] in higher imports to satisfy the consumer demand.

For each of the model variables, a tweak type must be given. For the agricultural exports and imports an *add* tweak is selected because in each year, the values must be added resp. subtracted from the values calculated by the model.

[25] According to statistic ~17% of agriculture products are exported and ~84% are consumed domestically https://old.stat.gov.kz/getImg?id=ESTAT289858).

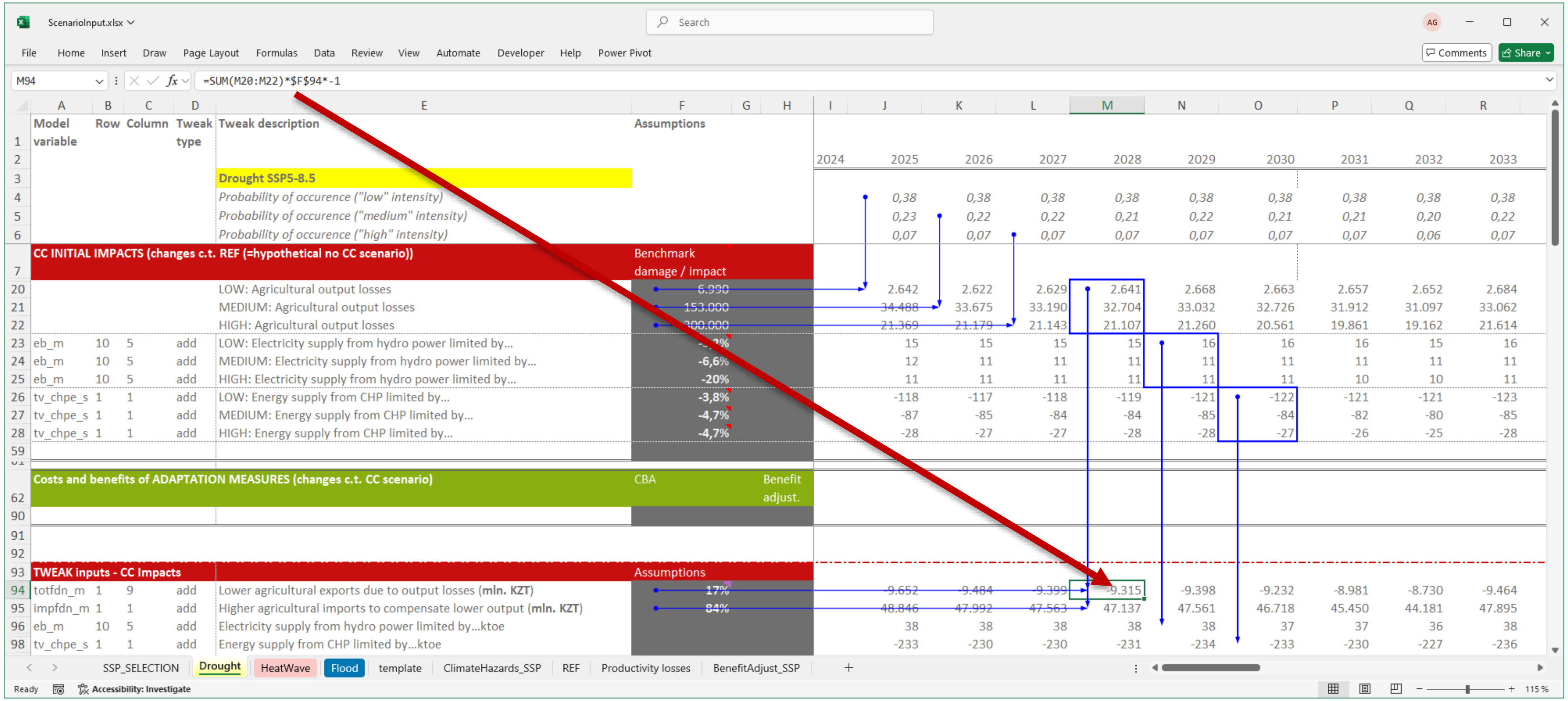


Figure 36: "Drought" worksheet

Source: Own illustration.

Implementation of the tweak inputs in the *Scenario* worksheet

The results of the preparatory work in the *ScenarioInput.xlsx* worksheet are then simply linked (or copied and pasted) into the *Scenario* worksheet in the *e3kz.xlsb* workbook (yellow cells in Figure 37). Linking cells has the advantage that if the underlying data is updated or another SSP scenario is selected, the tweaks in the *Scenario* worksheet are automatically updated.

Then, column E "Active tweak?" must be activated for all variables where the tweak should be active. Otherwise the tweak is inactive.

If necessary, also column F "Interpolate?" must be activated. The framework would then interpolate the given values for non-consecutive years.

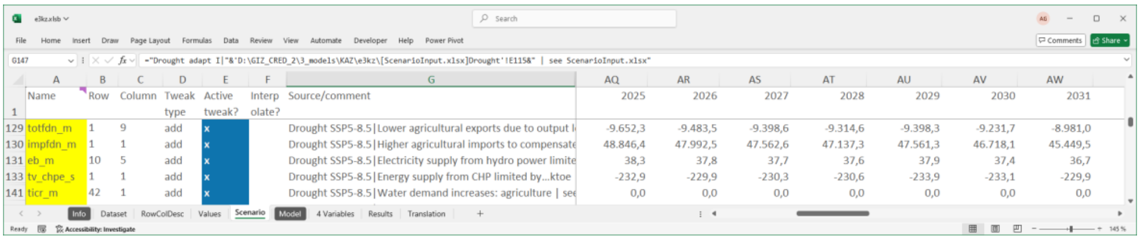


Figure 37: "Scenario" worksheet

Source: Own illustration.

Finally, the model must be executed by pressing the *Run* button on the *Model* worksheet. If the model run is successfully finished, results for all model variables are automatically stored in the *Results* worksheet (Figure 38).

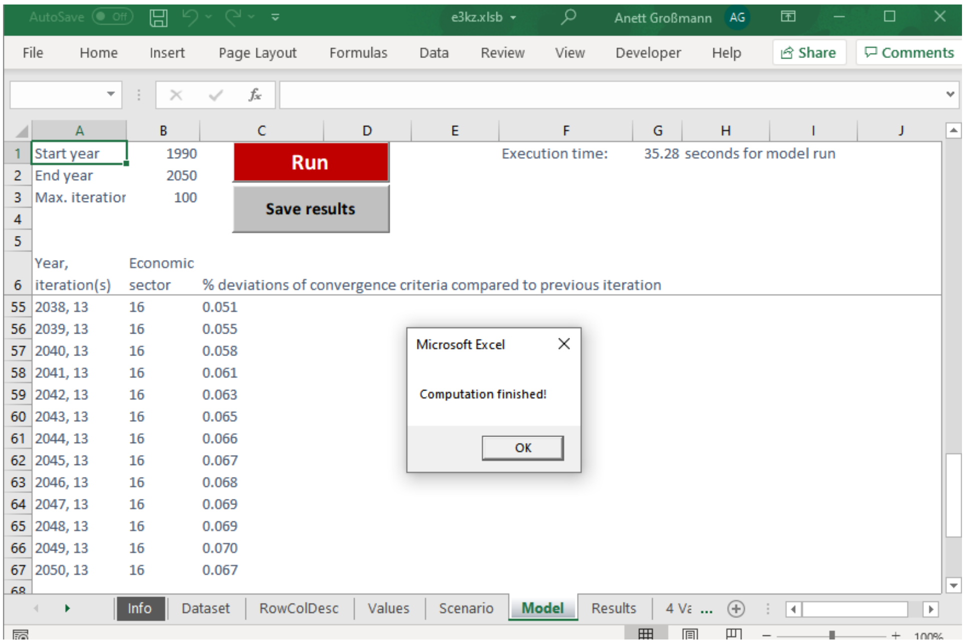


Figure 38: Model run

Source: Own illustration.

IMPORTANT: Each time the model is executed, new results are stored in the *Results* worksheet and thus overwrite previous results. Once the button *Save results* is executed, the current scenario results (*Results*, *4 Variables*[26]) and assumptions (*Scenario*) are stored in a MS Excel file in the folder *scenarios* with an appropriate filename, e. g. "drought" (cf. section 3). Thus, when carrying out another simulation, the results of the "drought" will not be overwritten.

4.2.3 Implementation of regional scenarios

The implementation of scenarios that will be evaluated also at subnational level follow the steps described in section 4.2.2. Additionally, the following steps must be taken:

- Climate hazard scenario
- Activate the tweaks for the respective climate hazard scenario in the sheet *Scenario* (c.f. section 4.2.2),
- Activate the *cca_s* variable that informs the e3.kz model that you are running a climate change (adaptation) scenario,
- According to your climate hazard scenario, activate the economic sector(s) and region(s) that are affected by selecting the corresponding row and column elements of the *sr_m(r,c)* variable. 20 regions are listed in the rows, 19 economic sectors in the columns. Make sure that for each selected matrix element, the value one (1) is given for <u>all</u> years.
- Activate the tweaks for the variables *emplr_m(r,c)*, *lpr_m*(r,c) and *emplss_v(r)* to which the REF results are assigned (see column G "REF results").
- ONLY if the results of the REF scenario are changed, replace all values for the variables *emplr_m(r,c)*, *lpr_m*(r,c) and *emplss_v(r)*. The scenario results are stored – once you pressed the button *Save results* – in an Excel file in the folder *Scenarios*. Open the file including the REF results and copy and paste the respective values into the *Scenario* sheet.
- Climate adaptation scenario
- Activate the tweaks from the regional climate hazard scenario,
- Activate the tweaks for the respective climate adaptation scenario (at national level)
- According to your climate adaptation scenario, activate the economic sector(s) and region(s) that are affected by selecting the corresponding row and column elements of the sr_m(r,c) variable.
- Deactivate the tweaks for the variables *emplr_m(r,c)*, *lpr_m*(r,c) and *emplss_v(r)* to which the REF results are assigned (see column G "REF results").
- Activate the tweaks for the variables *emplr_m(r,c)*, *lpr_m*(r,c) and *emplss_v(r)* to which the climate hazard results are assigned (see column G "CC scenario results …").
- Replace all values for the variables *emplr_m(r,c)*, *lpr_m(r,c)* and *emplss_v(r)* by the results of the respective climate change scenario. This scenario results are stored – once you pressed the button *Save results* – in an Excel file in the folder *Scenarios*. Open the file including the results from the respective climate change scenario and copy and paste the respective values into the *Scenario* sheet.

Note: Under CRED II, the subnational climate change and adaptation scenarios have not been updated.

[26] The pre-prepared evaluation tool *4 Variables* is based on the template *Eval1ScenarioTemplate.xlsb* stored in the folder *template* (see section 3). Any changes in this template will impact the evaluation possibilities in the worksheet *4 Variables*.

4.2.4 Evaluation of scenario results

Basically there are two options to look at the results: Either the projections (absolute values, index, growth rates) of different model variables of **ONE scenario** are considered or the (absolute and relative) differences of the scenario results for **TWO scenarios** are compared. While the first option is used to evaluate model interrelationships, the latter option is best suited for the evaluation of scenarios ("what-if" analysis).

Evaluation of ONE scenario

The *Results* worksheet contains the full set of historical and projected data. For policy analysis, a condensed view of the data is more practical. Model users can easily create customized views (dashboards) based on the *Results* worksheet.

A pre-prepared evaluation tool is shown in the worksheet *4 Variables*. The model user can select up to four variables (see *Dataset* worksheet) for ONE scenario which are displayed in graphical and table format. For each of the variables, the name, row and column must be given by the user (see red rectangle in Figure 39). Units (column D) are updated automatically.

Three display types are available to be selected from the list in cell B7:

- Absolute values in the respective units,
- Annual average growth rates and
- Index values for a user specified base year (cell E7).

The figure updates automatically after selecting the display type.

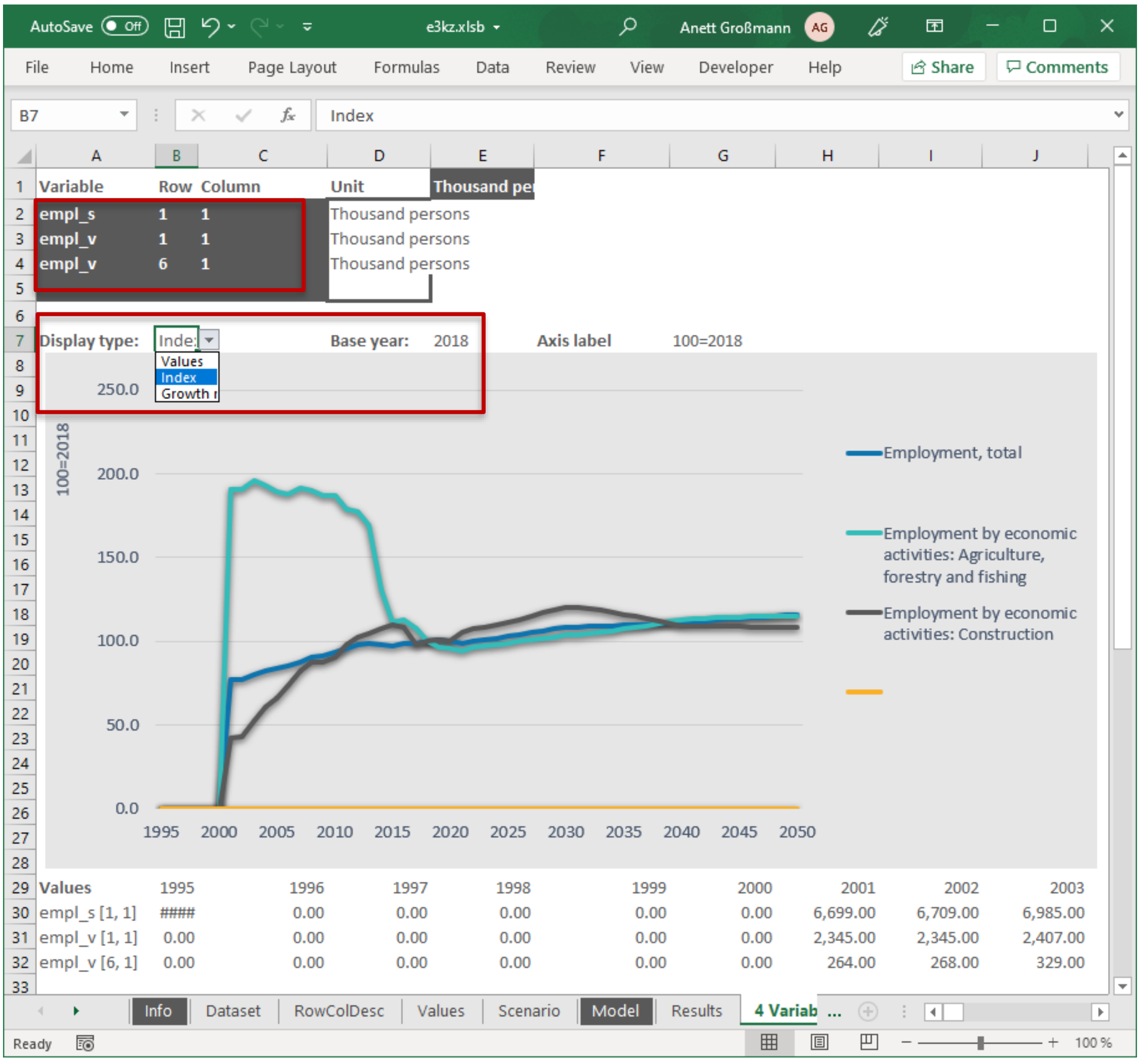


Figure 39: Evaluation tool "4 Variables"

Source: Own illustration.

For the evaluation of the regional economic indicators for ONE scenario, the evaluation tool *_Eval1ScenarioRegio_.xlsb* can be used which can be found in the *scenarios* folder. First, the user must update the list of scenarios in the *SelectScenarios* worksheet and select a scenario from the list. Then, the button "*2. Step: READ Results*" is activated (Figure 40).

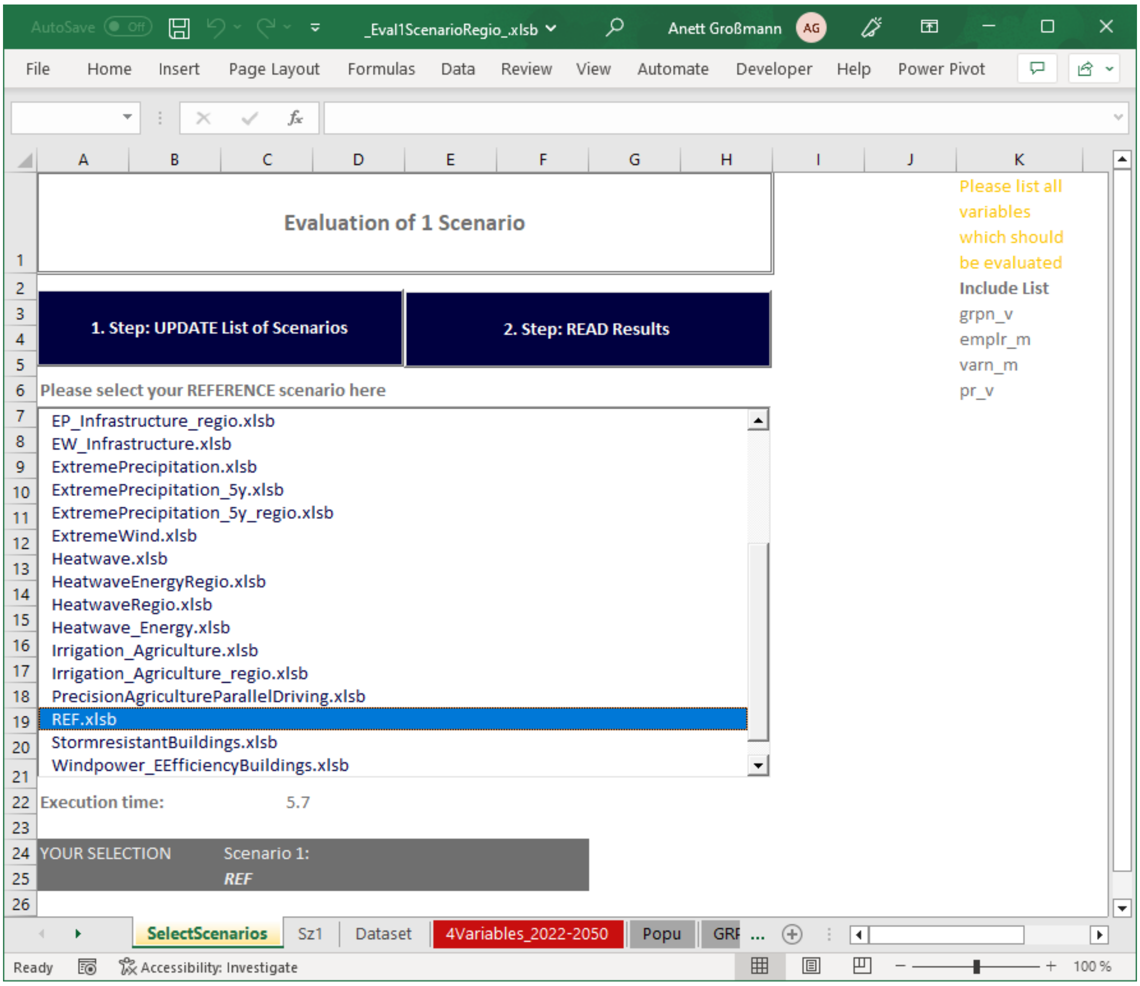


Figure 40: Evaluation tool _Eval1ScenarioRegio_.xlsb

Source: Own illustration.

The preconfigured graphs, tables and maps are updated and can be used to evaluate the results for the subnational regions.

Comparison and evaluation of TWO scenarios

To see the effects of a certain (alternative) scenario, it must be compared to another scenario that does not consider these assumptions. The differences between the scenarios can then be attributed to the different assumptions in the scenarios and the triggered reactions in the model.

The evaluation tool *_Compare2Scenarios_.xlsb* in the folder *scenarios* (cf. section 3) allows for a comparative analysis at national level and the tool *_Compare2ScenariosRegio_.xlsb* for the comparative analysis at subnational level. In a first step, the reference and the alternative scenario have to be selected. By pressing the button "*1. Step: UPDATE List of Scenarios*", all scenarios stored in the folder *scenarios* are displayed in the two list boxes. In the left (right) list box the scenario which should serve as reference (alternative) must be selected by clicking on it.

In the second step, the results of both scenarios are compared in relative and absolute values by activating the button "*2. Step: READ and COMPARE Results*". Basically, the deviations in absolute values and in percent can be calculated for all model variables and stored in this workbook. To speed up the comparison, the user should list only those model variables which need to be evaluated (column N in Figure 41).

Preconfigured graphs / dashboards – either for one selected year or as times series – for the most important e3.kz model variables are shown in different worksheets (Figure 42). The results are always given **as differences** for the selected model variables **between two scenarios**!

The tool *_Compare2Scenarios_.xlsb* comprises the following preconfigured graphs:

- Worksheet *Economy_AbsDiff*: GDP components, employment and real production by economic sectors for a single year in absolute values
- Worksheet *Economy_%Diff*: GDP components, employment and real production by economic sectors for a single year in relative values
- Worksheet *EnergyEmissions*: absolute and relative differences for CO_2 emissions and the energy balance
- Worksheet *4Variables_TimeSeries*: displays up to four selected model variables
- Worksheet *ScCompareFig_TimeSeries*: Employment by economic activities and GDP components in absolute and relative differences as time series (2020 to 2050)

The selection of a specific year is done in the worksheet *SelectScenarios* (see red rectangle in Figure 41) and is valid for all graphs that are referring to a single year. Once a new year is selected, all graphs are refreshed automatically.

Further evaluation sheets / dashboards with figures and tables based on the results in the worksheets *DiffAbs* and *Diff%* can be created by the user. For example, a set of indicators (e. g. output, employment) can be considered in a dashboard for only one economic sector (e. g. agriculture, construction) which is in focus.

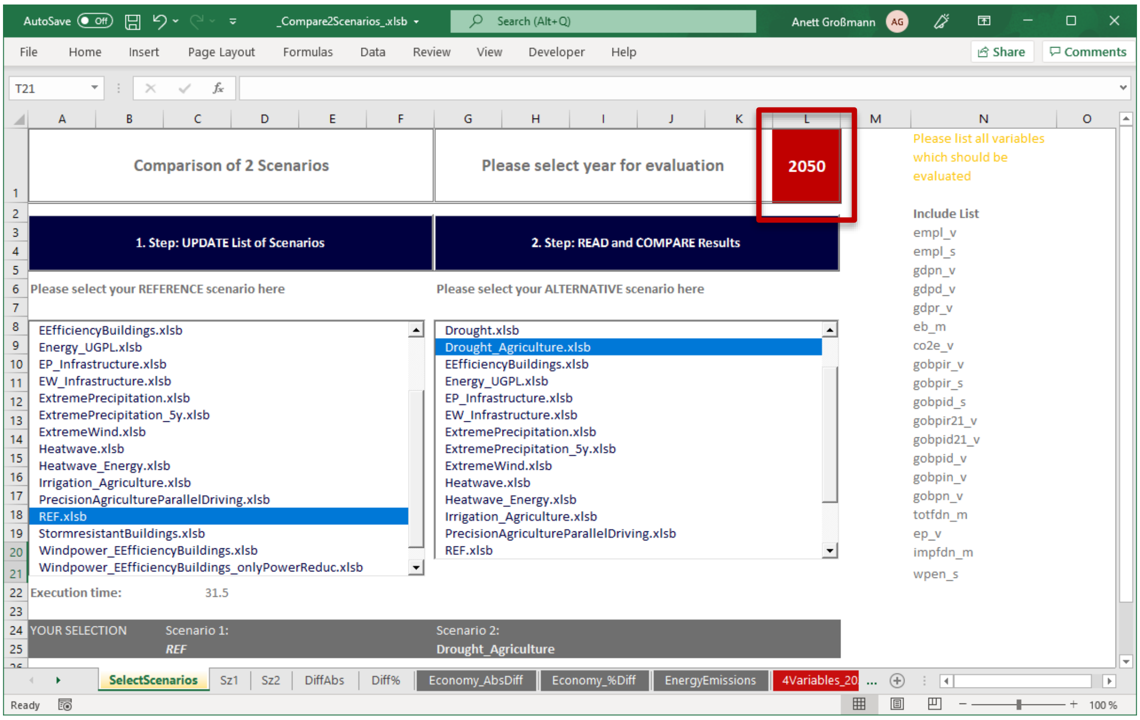


Figure 41: Evaluation tool _Compare2Scenarios_.xlsb

Source: Own illustration.

Additionally, for both selected scenarios the absolute values (NO differences) are stored in the "*Sz1*" resp. "*Sz2*" sheets. Thus, the model user can create a graph for ONE model variable including the development over time in each scenario and the difference (resp. deviations) between the two scenarios. An example can be found for employment in the sheet "*ScCompareFig2025-2050*" in the workbook "*_Compare2Scenarios_.xlsb_*".

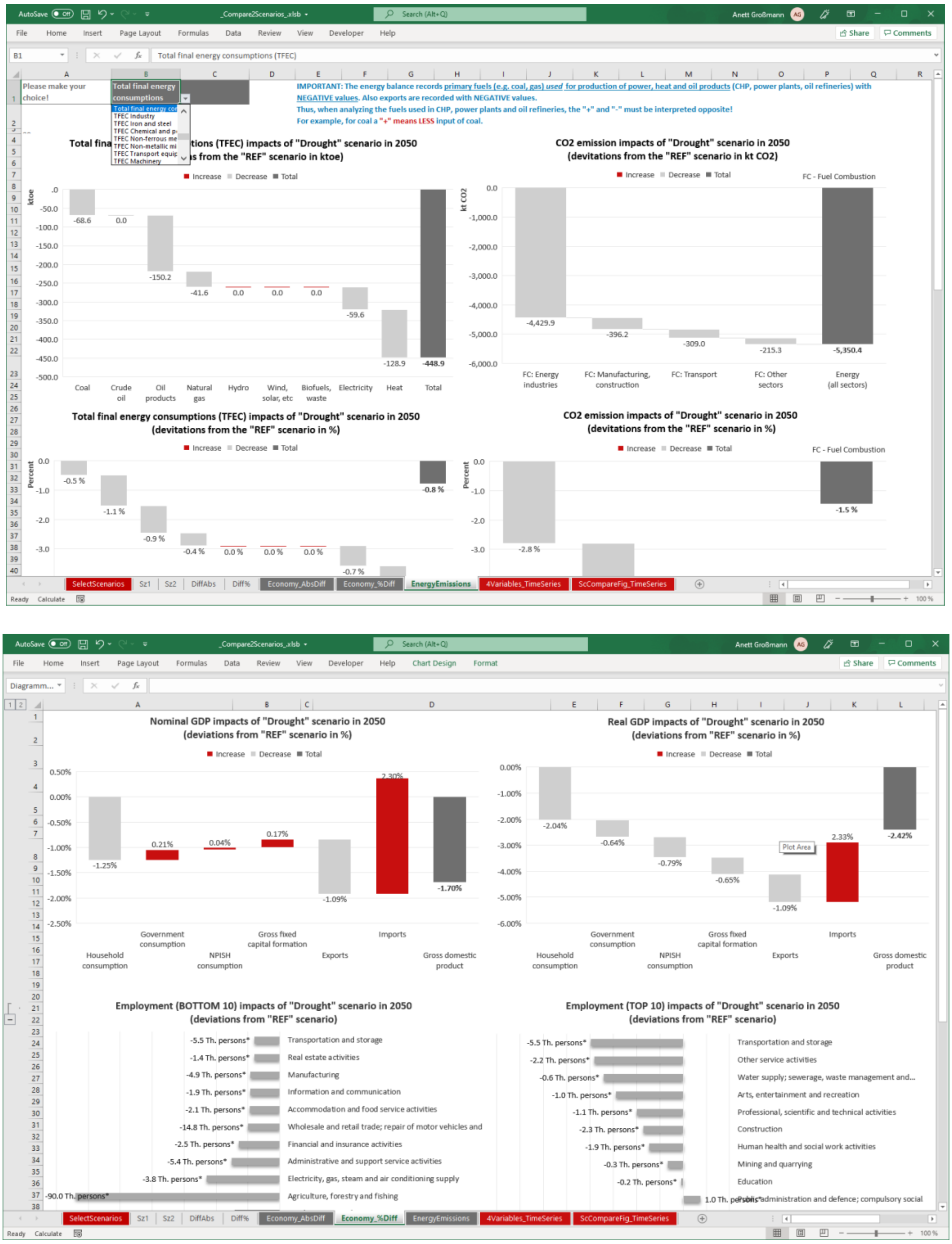


Figure 42: Selected examples of comparative evaluation of two scenarios

Source: Own illustration.

For the evaluation of the exemplary "drought" scenario, the reference scenario (hypothetical no climate change scenario) is selected as the reference and the drought scenario as the alternative scenario. The pre-configured evaluation tool is then used for doing the macroeconomic analysis of droughts to detect the inter-sectoral and overall effects.

A drought is impacting the macroeconomy negatively. Export chances cannot be realized and higher imports for agricultural products and electricity dampen the economic growth. Furthermore, lower employment and income levels reduce the spending opportunities of private households. Other imports are decreasing due to lower economic activity and support economic growth. The import dependency is generally high and thus lower demand for intermediate and finished products results in lower imports (Figure 43).

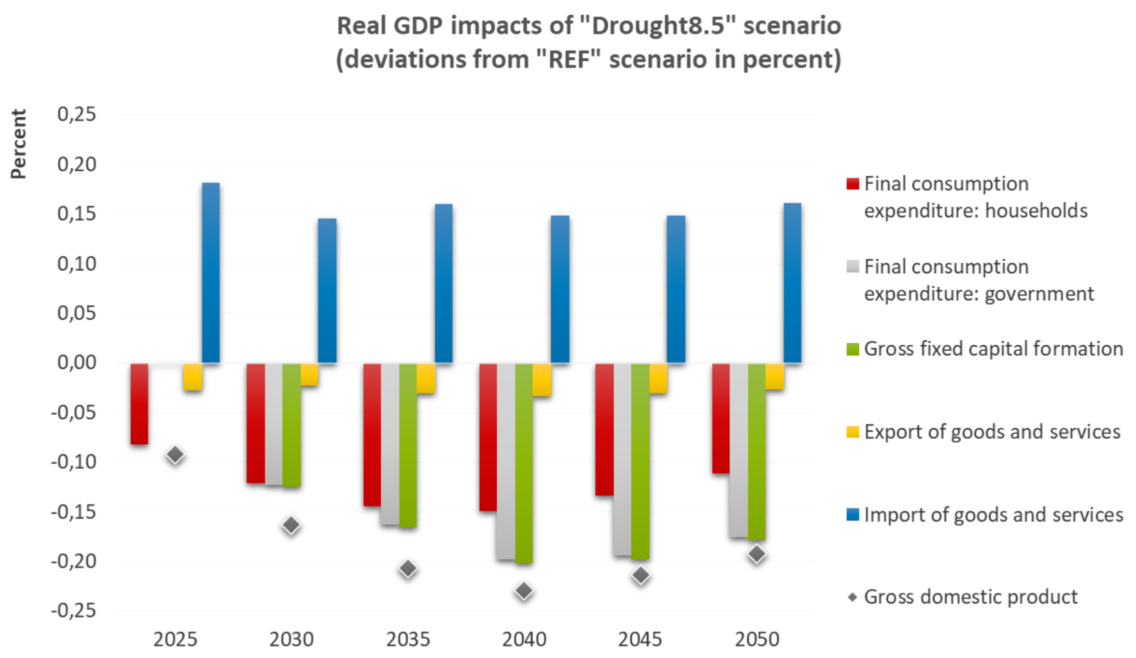


Figure 43: "Drought" scenario (SSP5-8.5): macroeconomic effects, 2025-2050, in percent

Source: Own illustration.

For the economic sectors, the impacts are diverse. Production is in particular constrained in the agriculture and energy sector (Figure 44). Other sectors are indirectly affected by the drought via economic interlinkages. For example, the demand for intermediate goods in the agricultural sector (e. g. pesticides produced by the chemical industry) is at a lower level compared to the "no drought" (REF) scenario. Lower consumer expenditures by private households on food, among other things, causes further production adjustments.

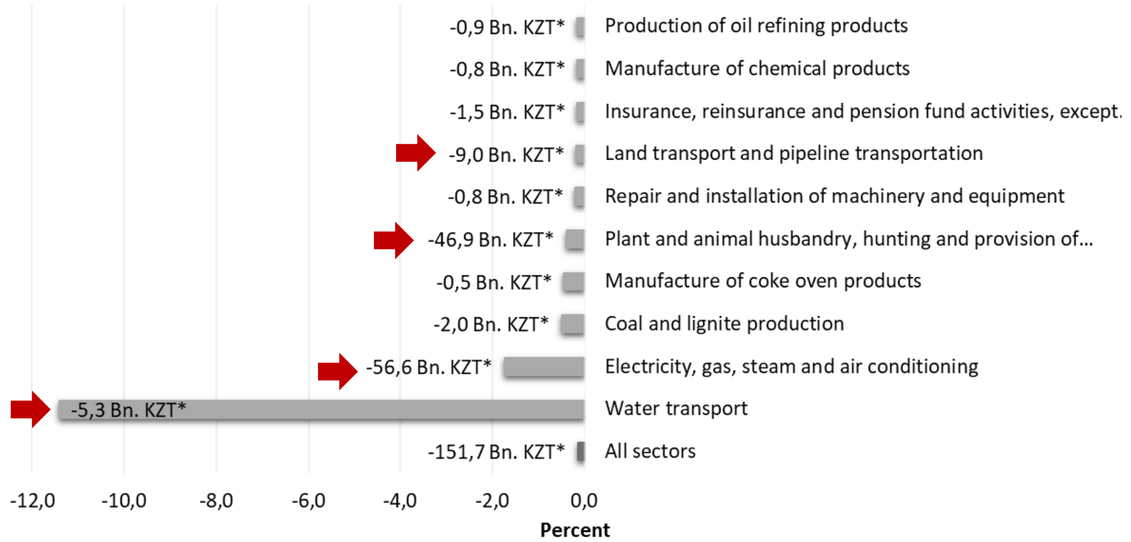


Figure 44: "Drought" scenario (SSP5-8.5): real production by economic sectors, in 2050, deviations from a hypothetical "No drought" (REF) scenario in percent (x-axis) and Bn. KZT (*)

Source: Own illustration based on e3.kz results

Employment follows the production considering the sectoral labor-intensities which is highest in the agriculture and many service sectors (e. g. wholesale). Figure 45 shows the change in employment compared to the REF scenario. Jobs are at risk especially in agriculture.

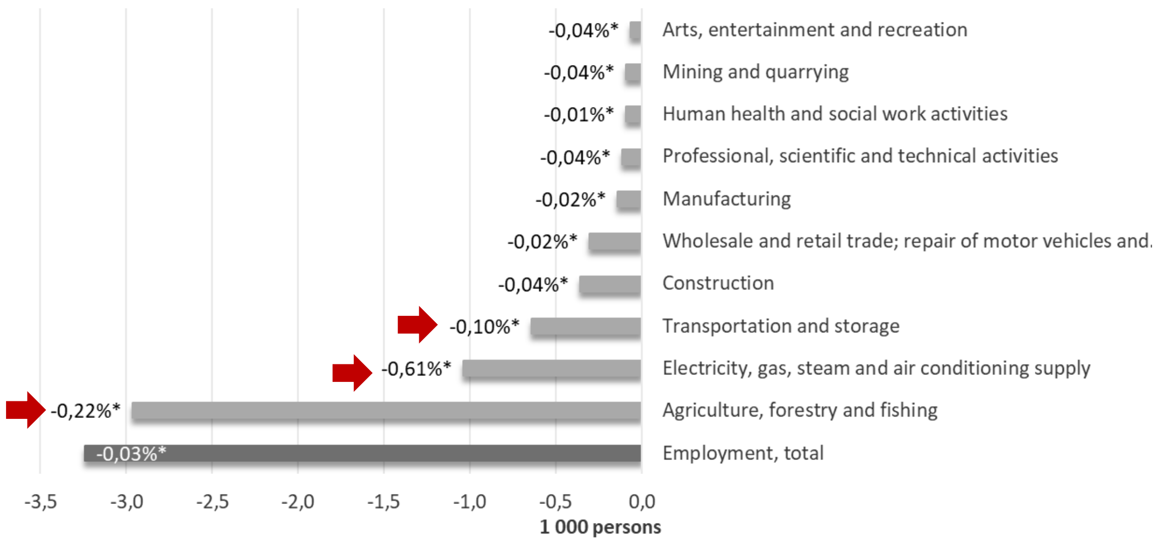
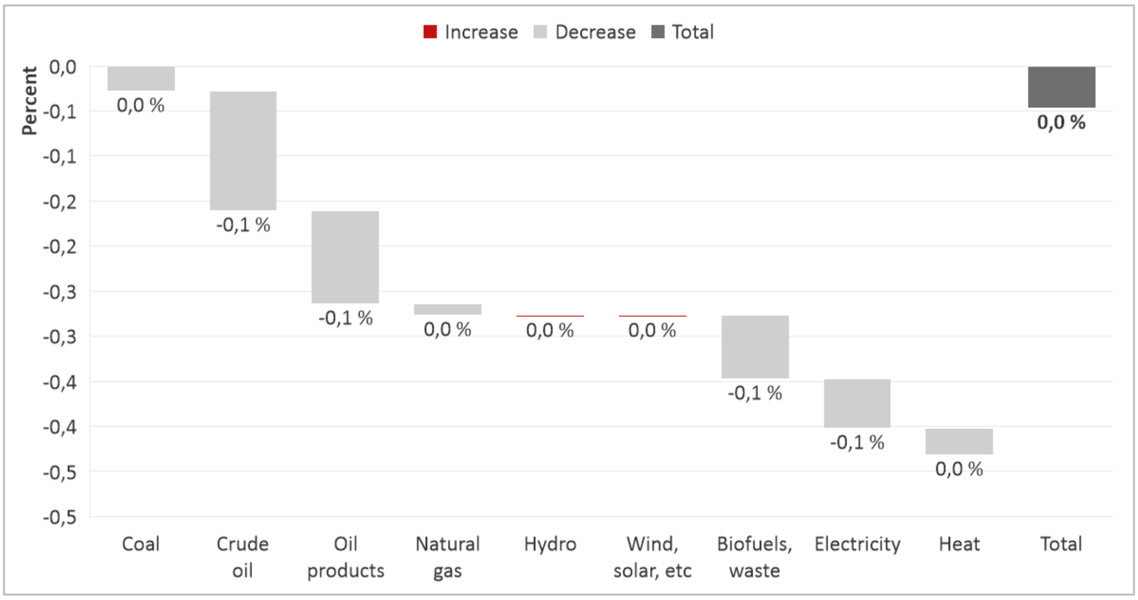


Figure 45: "Drought" scenario (SSP5-8.5): employment by sectors, in 2050, deviations from a hypothetical "No drought" (REF) scenario in 1,000 persons

Source: Own illustration based on e3.kz results

The impacts on the environment are small. Limited economic growth caused by droughts results in lower final energy consumption (Figure 46) and CO_2 emissions (Figure 47). In 2050, TFEC is by 30 ktoe resp. 0.05% lower compared to a “no drought” (REF) scenario which is based on less fossil fuels. The use of renewable energy remains at the same level as in a “no drought” (REF) scenario indicated by a zero percentage deviation resp. zero ktoe.



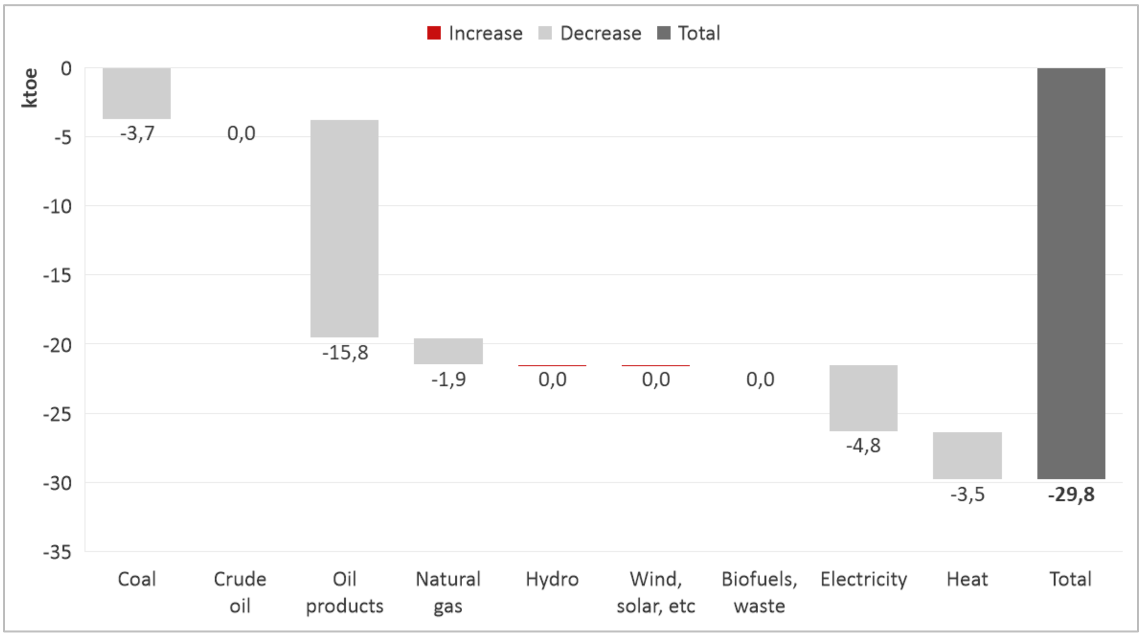
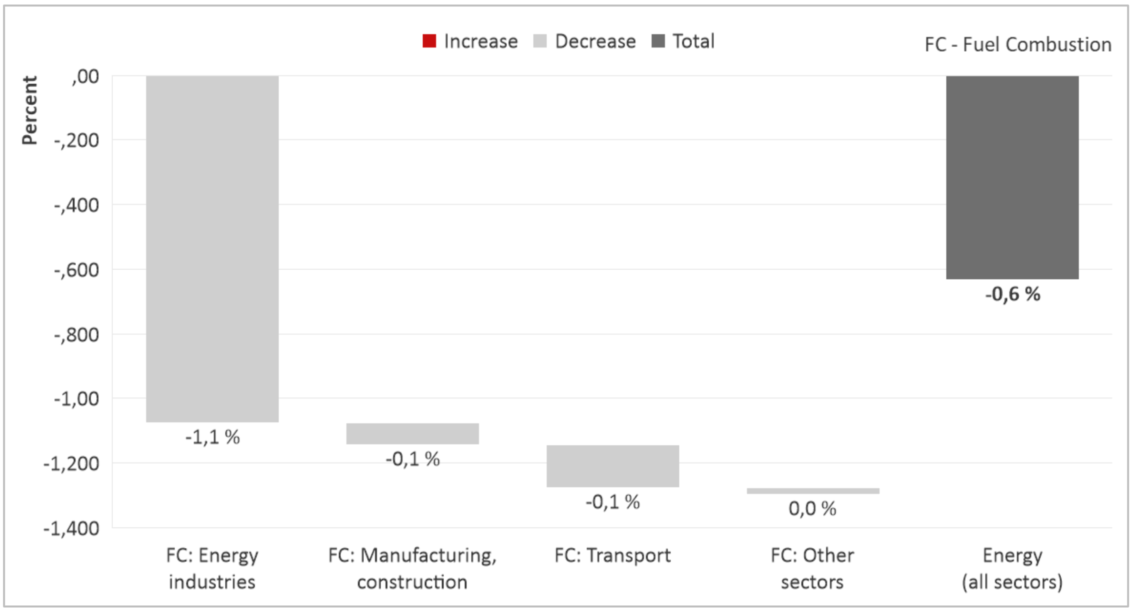


Figure 46: “Drought” scenario (SSP5-8.5): energy demand, in 2050, deviations from a hypothetical “No drought” (REF) scenario in ktoe (top figure) and percent (bottom figure)

Source: Own illustration based on e3.kz results.

Another positive impact is related to the temporary lower production of the thermoelectrical plants mainly operating with fossil fuels which results in a decreasing total primary energy supply in particular for coal and natural gas.



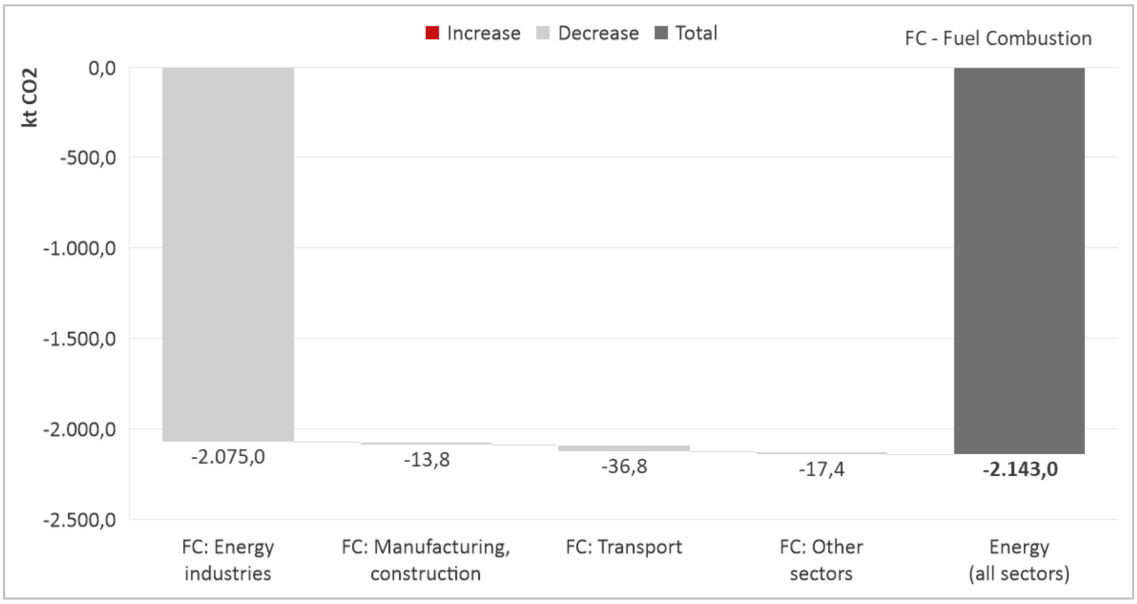


Figure 47: "Drought" scenario (SSP5-8.5): CO_2 emissions, in 2050, deviations from a hypothetical "No drought" (REF) scenario in kt CO_2 (top figure) and percent (bottom figure)

Source: own illustration based on e3.kz results

The lower energy demand of fossil fuels leads to an overall reduction in emissions of 0.6% or 2.1 Mt CO_2 (Figure 47). In the energy industries, CO_2 emissions can be reduced the most compared to a "no drought" (REF) scenario.

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6. EXCURSION: IO ANALYSIS

An IO table is the basis of IO analysis which is able to reveal how different sectors of an economy are interconnected and how a change in one economic sector affects all other sectors. Thus, with IO analysis value chains, customer-supplier relationships and cost structures of economic sectors can be explored. It us useful for impact analysis which helps to detect key industries within an economy and the vulnerability of economic sectors to quantity and price effects. Wassily Leontief, often referred to as pioneer of IO based economics, developed the first IO model and received the Nobel prize in 1973.

An IO table (IOT) provides a comprehensive picture of the supply of goods and services by domestic production and imports, its composition by intermediate flow (quadrant I, Figure 48) and value added (quadrant III) as well as the use of goods and services for final demand (quadrant II).

The IOT is supplemented by tables showing the flow of domestic goods and services as well as the distribution of imports for intermediate and final use (see Figure 48 for an aggregated view. The full tables are part of the e3.kz dataset).

The columns of the IOT show the monetary value of (intermediate and labor) inputs by economic sectors (e. g. manufacturing) which are either domestically produced or imported. For example, manufacturing purchases amongst other services from Kazakh suppliers worth KZT 2,257 bn. and KZT 12 bn. services offered from abroad to produce KZT 12,123 bn. of output (middle and bottom Figure 48 highlighted in yellow).

The rows of the intermediate flow matrix display the value of the sales of intermediate or final goods by economic sectors. E. g., KZT 175 bn. of "Electricity, gas, water" are sold from domestic suppliers to "agriculture, forestry,..." (and KZT 14 bn. are sold from abroad) as intermediate input and KZT 1,061 bn. (KZT 14 bn. imports) are sold as "final demand" (middle and bottom Figure 48 highlighted in orange).

The actual symmetric IO table of Kazakhstan reflects 68 product groups (CPA Code Appendix 2). The value of output is structured by intermediate consumption, compensation of employees, taxes and subsidies on production and imports, depreciation as well as gross operating surplus plus mixed income. The final demand categories consist of final consumption expenditure (private households, non-profit institutions serving households (NPISH), government), gross capital formation (gross fixed capital formation, change in inventories, acquisitions less disposals of valuables) and exports of goods and services (

Appendix 3).

The IO relations as seen in the tables can be transformed into a set of mathematical equations. Technology-based domestic input coefficients A are introduced to transform the equations in a way which allows applying methods of matrix algebra to find its mathematical solutions. The result is the well-known Leontief-Inverse $(I - A)^{-1}$. The Leontief equation can be applied to answer the questions: How does production react when final demand changes? Which industries are (directly and indirectly) affected by these changes? Due to the high import dependency of Kazakhstan, it is useful to explicitly consider the production-induced imports im^X (not to be confused with imported final products) that are induced from additional domestic production.

$$X = (I - A)^{-1} \cdot Y$$

X – Output; Y – Final demand; I – Identity matrix

$$im^X = (A^{im}) \cdot ((I - A)^{-1} \cdot Y)$$

A^{im} – Input coefficient matrix for imports

IOT (2017, bn. Tenge)	Agriculture, forestry, fishing, mining	Manu-facturing	Electricity, gas, water	Construction	Services	*Final demand*	**Total use**
Agriculture, forestry, fishing, mining	1,833	3,038	73	96	311	*14,267*	***19,618***
Manufacturing	2,320	1,267	470	1,199	3,629	*13,378*	***22,261***
Electricity, gas, water	189	96	52	25	777	*1,075*	***2,214***
Construction	52	3	19	155	891	*4,339*	***5,459***
Services	3,831	2,268	468	1,293	10,284	*29,172*	***47,316***
Value added	10,447	5,407	1,040	2,067	29,507		
Output	18,767	12,123	2,128	4,857	45,630		
Imports	850	10,138	85	602	1,686		
Total Supply	**19,618**	**22,261**	**2,214**	**5,459**	**47,316**		

Intermediate flow

Total supply = total use

DOMESTIC IOT (2017, bn. Tenge)	Agriculture, forestry, fishing, mining	Manufacturing	Electricity, gas, water	Construction	Services	*Final demand*	**Total use**
Agriculture, forestry, fishing, mining	1,698	2,740	56	85	264	*13,926*	***18,767***
Manufacturing	1,184	680	323	924	1,715	*7,297*	***12,123***
Electricity, gas, water	175	93	49	23	727	*1,061*	***2,128***
Construction	45	3	16	88	584	*4,120*	***4,857***
Services	3,627	2,257	456	1,219	9,420	*28,651*	***45,630***
Intermediate use	*6,728*	*5,772*	*900*	*2,339*	*12,711*		
Value added	10,447	5,407	1,040	2,067	29,507		
Output	18,767	12,123	2,128	4,857	45,630		
Imports	850	10,138	85	602	1,686		
Total Supply	**19,618**	**22,261**	**2,214**	**5,459**	**47,316**		

IMPORTED IOT (2017, bn. Tenge)	Agriculture, forestry, fishing, mining	Manufacturing	Electricity, gas, water	Construction	Services	*Final demand*	**Total use**
Agriculture, forestry, fishing, mining	136	299	17	11	47	*341*	***850***
Manufacturing	1,136	587	147	274	1,914	*6,080*	***10,138***
Electricity, gas, water	14	2	3	2	50	*14*	***85***
Construction	7	0	2	67	307	*218*	***602***
Services	204	12	11	75	864	*521*	***1,686***
Intermediate use	*1,497*	*900*	*181*	*428*	*3,182*		

Figure 48: Simplified IO table for Kazakhstan (2017) for imports (bottom figure), domestic production (middle figure) and both combined (top figure).

Source: own illustration based on COMSTAT (Қазақстан Республикасының 2018 жылғы «Шығындар - Шығарылым» кестелері, 2019 жыл)

Further details can be explored for example in Eurostat (2008) and UN (2018).

7. APPENDIX

Appendix 1: Model core routines for use by model builders

Subroutine Name	Description
Function CreateMat(ByVal rows As Integer, ByVal cols As Integer) As Double()	Create a matrix from given size
Function CreateUnitMatrix(ByVal size As Integer) As Double()	Create a unit matrix from given size
Function MatAdd(ByVal m1 As Variant, ByVal m2 As Variant) As Variant	Add two matrices
Function MatColSum(ByVal var As Variant, ByVal col) As Double	Element-by-element division for two matrices
Function MatColSumRange(ByVal var As Variant, ByVal column As Integer, ByVal firstRow As Integer, ByVal lastRow As Integer) As Double	Calculate the inverse of a matrix
Function MatDivE(ByVal m1 As Variant, ByVal m2 As Variant) As Variant	Multiply two matrices
Function MatInv(ByVal m1 As Variant) As Variant	Element-by-element multiplication of two matrices
Function MatMult(ByVal m1 As Variant, ByVal m2 As Variant) As Variant	Subtract two matrices
Function MatMultE(ByVal m1 As Variant, ByVal m2 As Variant) As Variant	Calculate the sum of a matrix
Function MatRowSum(ByVal var As Variant, ByVal row) As Double	Transpose a matrix
Function MatRowSumRange(ByVal var As Variant, ByVal row As Integer, ByVal firstColumn As Integer, ByVal lastColumn As Integer) As Double	Add two vectors
Function MatSub(ByVal m1 As Variant, ByVal m2 As Variant) As Variant	Subtract two vectors
Function MatSum(ByVal var As Variant) As Double	Calculate the sum of a vector
Function MatTrans(ByVal m1 As Variant) As Variant	Calculates the sum over a specified range in a vector
Function VecAdd(ByVal v1 As Variant, ByVal v2 As Variant) As Variant	Calculate the sum of a given column in a matrix
Function VecSub(ByVal v1 As Variant, ByVal v2 As Variant) As Variant	Calculates the sum over a specified column range in a matrix
Function VecSum(ByVal var As Variant) As Double	Calculate the sum of a given row in a matrix
Function VecSumRange(ByVal var As Variant, ByVal firstRow As Integer, ByVal lastRow As Integer) As Double	Calculates the sum over a specified row range in a matrix
Sub SetTo(ByRef var As Variant, ByVal val As Double)	Set all elements of a matrix/vector to a given value
Sub Tweak(ByVal t As Integer, ByVal lastData As Integer, ByRef var As Variant, ByVal varName As String)	Applies available tweaks to a given variable

Appendix 2: Product classification of the Kazakh IO table

Serial number	CPA code	Row description
1	01	Agriculture, hunting products and related services
2	02	Forestry, logging products and related services
3	03	Fish and other fishing products; aquaculture; auxiliary fishing services
4	05	Coal and lignite
5	061	Crude oil
6	062	Natural gas in a liquid or gaseous state
7	071	Iron ores
8	072	Non-ferrous metals
9	08	Products of the mining industry
10	09	Support services to the mining industry
11	10-11	Food products, beverages
12	12	Tobacco products
13	13	Textiles
14	14	Wearing apparel
15	15	Leather and related products
16	16	Wood and articles of wood and cork (except furniture), articles of straw and plaiting materials
17	17	Paper and paper products
18	18	Printing and reproduction services
19	191	Products of coke oven
20	192	Oil refining products
21	20	Chemicals and chemical products
22	21	Pharmaceutical products and basic pharmaceuticals
23	22	Rubber and plastic products
24	23	Other non-metallic mineral products
25	241	Basic ferrous metals: iron, cast iron, steel and ferroalloys
26	242	Pipes of various diameters, hollow profiles and fittings for stainless steel pipes
27	243	Other steel products of primary processing
28	244	Basic precious metals and other non-ferrous metals
29	245	Foundry services
30	25	Finished metal products, except machinery and equipment
31	26	Computers, electronics and optical products
32	27	Electrical equipment
33	28	Machinery and equipment nec

34	29	Cars, trailers and semitrailers
35	30	Other transport equipment
36	31	Furniture
37	32	Other finished goods
38	33	Repair and installation services of machinery and equipment
39	351	Power generation and distribution services
40	352	Flammable gas; gas distribution services for gas pipelines
41	353	Refrigerated steam and air conditioning services
42	36-39	Water supply; sewerage, waste management services
43	41-43	Construction works
44	45	Wholesale and retail services; repair services of motor vehicles and motorcycles
45	46	Wholesale trade services, except of motor vehicles and motorcycles
46	47	Retail services, except motor vehicles and motorcycles
47	49	Land transport services and pipelines
48	50	Water transport services
49	51	Air transport services
50	52	Storage services and ancillary transportation services
51	53	Postal and courier services
52	55	Accommodation services
53	56	Food and beverage service activities
54	58-63, 61 басқа	Information services
55	61	Communication services
56	64	Except financial services, insurance and pension services
57	65	Insurance, reinsurance and pension services, except compulsory social security services
58	66	Support services for financial intermediation and insurance
59	68	Real estate services
60	69-75	Professional, scientific and technical services
61	77-82	Activities in the field of administrative and support services
62	84	Public administration and defense services; compulsory social security services
63	85	Education services
64	86	Health services
65	87-88	Social services
66	90-93	Arts, entertainment and recreation services
67	94-96	Other services

68	97-98	Services of households hiring domestic workers and the production of goods and services for own use

Appendix 3: Final demand items and total demand of the Kazakh IO table

Serial number	Column description
1	Final consumption expenditures: household
2	Final consumption expenditures: government
3	Final consumption expenditures: NPISH
4	Final consumption expenditures: total
5	Gross fixed capital formation
6	Change in inventories
7	Acquisitions less disposals of valuables
8	Gross capital formation
9	Export of goods and services
10	Total final demand
11	Total demand

Appendix 4: Classification of economic sectors

Serial number	NACE code	Row description
1	01	Plant and animal husbandry, hunting and provision of services in these areas
2	02	Forestry and logging
3	03	Fishery and aquaculture
4	05	Coal and lignite production
5	06	Extraction of crude oil and natural gas
6	07	Production of metal ores
7	08	Other sectors of the mining industry
8	09	Technical services in the mining industry
9	10	Food production
10	11	Manufacture of beverages
11	12	Manufacture of tobacco products
12	13	Manufacture of textiles
13	14	Manufacture of clothing

14	15	Manufacture of leather and related products
15	16	Manufacture of wood and cork, except furniture; manufacture of articles of straw and plaiting material
16	17	Manufacture of paper and paper products
17	18	Printing and reproduction of recorded materials
18	191	Manufacture of coke oven products
19	192	Production of oil refining products
20	20	Manufacture of chemical products
21	21	Manufacture of basic pharmaceutical products
22	22	Manufacture of rubber and plastic products
23	23	Manufacture of other non-metallic mineral products
24	24	Metallurgical industry
25	25	Manufacture of fabricated metal products, except machinery and equipment
26	26	Development of computers, electronic and optical products
27	27	Manufacture of electrical equipment
28	28	Manufacture of machinery and equipment not included in other categories
29	29	Manufacture of motor vehicles, trailers and semi-trailers
30	30	Manufacture of other vehicles
31	31	Manufacture of furniture
32	32	Manufacture of other finished products
33	33	Repair and installation of machinery and equipment
34	35	Electricity, gas, steam and air conditioning
35	36-39	Water supply; sewerage, waste management and remediation activities
36	41-43	Construction
37	45	Wholesale and retail trade and repair of motor vehicles and motorcycles
38	46	Wholesale trade, except of motor vehicles and motorcycles
39	47	Retail trade, except of motor vehicles and motorcycles
40	49	Land transport and pipeline transportation
41	50	Water transport
42	51	Commercial air traffic
43	52	Warehousing and support activities for transportation
44	53	Postal and courier services
45	55	Accommodation services
46	56	Food and beverage services
47	58-63, кроме 61	Information services
48	61	Communication services

49	64	Excluding financial services, insurance and pension funds
50	65	Insurance, reinsurance and pension fund activities, except for compulsory social insurance
51	66	Support activities for financing and insurance services
52	68	Real estate transactions
53	69	Activity in the field of law and accounting
54	70	Parent company activity; management consulting
55	71	Activities in the field of architecture, engineering research, technical testing and analysis
56	72	Research and development
57	73	Research of advertising activity and market conditions
58	74	Other professional, scientific and technical activities
59	75	Veterinary activity
60	77	Leasing, renting, leasing
61	78	Employment
62	79	Activities of tour operators, travel agents and other service providers in the field of tourism
63	80	Security and inquiry services
64	81	Activity in the area of maintenance of buildings and territories
65	82	Activity in the field of administrative, management, economic and other support services
66	84	Public administration and defense; compulsory social security
67	85	Education
68	86	Activity in the field of health care
69	87-88	Social services
70	90-93	Art, entertainment and recreation
71	94-96	Other services
72	97-98	Household service that hires a domestic worker and produces goods and services for personal use

Appendix 5: Employment classification by economic sectors

Serial number	Row description
1	Agriculture, forestry and fishing
2	Mining and quarrying
3	Manufacturing
4	Electricity, gas, steam and air conditioning supply
5	Water supply; sewerage, waste management and remediation activities

6	Construction
7	Wholesale and retail trade; repair of motor vehicles and motorcycles
8	Transportation and storage
9	Accommodation and food service activities
10	Information and communication
11	Financial and insurance activities
12	Real estate activities
13	Professional, scientific and technical activities
14	Administrative and support service activities
15	Public administration and defence; compulsory social security
16	Education
17	Human health and social work activities
18	Arts, entertainment and recreation
19	Other service activities
20	Activities of households employing staff; production for own use
21	Activities of extraterritorial organizations and bodies

Appendix 6: National account items

Serial number	Item code	Row description
1	P1	Output at basic prices (received)
2	D21-D31	Taxes less subsidies on products
3	P2	Intermediate consumption (payed)
4	B1g	Gross value added
5	D1	Compensation of employees (payed)
6	D29	Other taxes on production (payed)
7	B2g/B3g	Gross operating surplus, gross mixed income
8	D1	Compensation of employees (received)
9	D2-D3	Taxes less subsidies on production and import
10	D4	Property income (received)
11	D4	Property income (payed)
12	B5g	Gross national income
13	D5	Current taxes on income, property (received)
14	D61	Social security contributions (received)
15	D62	Social benefits, except for social transfers in kind (received)

16	D7	Other current transfers (received)
17	D5	Current taxes on income, property (payed)
18	D61	Social security contributions (payed)
19	D62	Social benefits, except for social transfers in kind (payed)
20	D7	Other current transfers (payed)
21	B6g	Gross disposable income
22	D63	Social transfers in kind (received)
23	D63	Social transfers in kind (payed)
24	B7g	Adjusted disposable income
25	D8	Adjustment to changes in the net value of household pension funds (received)
26	D8	Amendments to changes in household pension rights (payed)
27	P3	Final consumption expenditures (payed)
28	B8g	Gross savings
29	D9	Capital transfers (received)
30	D9	Capital transfers (payed)
31	P51g	Gross fixed capital formation (payed)
32	P51c	Consumption of fixed capital (payed)
33	P52 AN12	Changes in inventories (payed)
34	B9	Net lending (+) / net borrowing (-)
35		Statistical discrepancy

Appendix 7: GDP components (expenditure approach)

Serial number	Row description
1	Final consumption expenditure: total
2	Final consumption expenditure: households
3	Final consumption expenditure: government
4	Final consumption expenditure: non-profit institutions serving households (NPISHs)
5	Gross capital formation
6	Gross fixed capital formation
7	Changes in inventories
8	Net export
9	Export of goods and services
10	Import of goods and services
11	Statistical discrepancy
12	Gross domestic product

Appendix 8: Population structure

Serial number	Row description
1	Total population
2	Population < 16 years
3	Population at working age (16 to 59 years (until 1998) / 16 to 62 years (1999-))
4	Population > 59 years (until 1998) / >63 years (1999-))

Appendix 9: Simplified SNA

		Uses	Resources
		PRODUCTION ACCOUNT	
Gross Output	P1		sna_v(t)(1)
Taxes less subsidies on products	D21-D31		sna_v(t)(2)
Intermediate consumption	P2	sna_v(t)(3)	
Gross domestic product/ gross value added	B1g		sna_v(t)(4)
		GENERATION OF INCOME ACCOUNT	
Gross domestic product/ gross value added	B1g		sna_v(t)(4)
Compensation of employees	D1	sna_v(t)(5)	
Other taxes on production (and imports minus subsidies)	D29	sna_v(t)(6)	
Gross operating surplus and gross mixed income	B2g/B3g		sna_v(t)(7)
		ALLOCATION OF PRIMARY INCOME ACCOUNT	
Operating surplus and mixed income	B2g/B3g		sna_v(t)(7)
Compensation of employees	D1		sna_v(t)(8)
Taxes on production and imports minus subsidies	D2-D3		sna_v(t)(9)
Property income	D4	sna_v(t)(11)	
Property income	D4		sna_v(t)(10)
Gross national income / primary income	B5g		sna_v(t)(12)

		SECONDARY DISTRIBUTION OF INCOME ACCOUNT	
Gross national income / primary income	B5g		sna_v(t)(12)
Current taxes on income, wealth	D5	sna_v(t)(17)	
Current taxes on income, wealth	D5		sna_v(t)(13)
Social security contributions	D61	sna_v(t)(18)	
Social security contributions	D61		sna_v(t)(14)
Social benefits, except for social transfers in kind	D62	sna_v(t)(19)	
Social benefits, except for social transfers in kind	D62		sna_v(t)(15)
Other current transfers	D7	sna_v(t)(20)	
Other current transfers	D7		sna_v(t)(16)
Gross disposable income	B6g		sna_v(t)(21)
Social transfers in kind	D63	sna_v(t)(23)	
Social transfers in kind	D63		sna_v(t)(22)
Adjusted disposable income	B7g		sna_v(t)(24)
		USE OF DISPOSABLE INCOME ACCOUNT	
Gross disposable income	B6g		sna_v(t)(21)
Adjust. for the change in net equity of households in pension funds	D8	sna_v(t)(26)	
Adjust. for the change in net equity of households in pension funds	D8		sna_v(t)(25)
Final consumption expenditure	P3	sna_v(t)(27)	
Gross saving	B8g		sna_v(t)(28)

		Change in assets	Changes in liabilities and net worth
		Capital Account	
Gross saving	B8g		sna_v(t)(28)
Capital transfer	D9 (-)		sna_v(t)(30)
Capital transfer	D9 (+)		sna_v(t)(29)
Gross fixed capital formation	P51g	sna_v(t)(31)	
Changes in inventories	P52AN12	sna_v(t)(33)	
Statistical discrepancy		sna_v(t)(35)	
Net lending/net borrowing	B9	sna_v(t)(34)	

Appendix 10: Structure of the energy balance

Serial number	Row description
1	Production
2	Imports
3	Exports
4	International marine bunkers
5	International aviation bunkers
6	Stock changes
7	TPES
8	Transfers
9	Statistical differences
10	Electricity plants
11	CHP plants
12	Heat plants
13	Gas works
14	Oil refineries
15	Coal transformation
16	Liquefication plants
17	Other transformation
18	Energy industry own use
19	Losses
20	Total final consumption
21	Industry
22	Iron and steel
23	Chemical and petrochemical
24	Non-ferrous metals
25	Non-metallic minerals
26	Transport equipment
27	Machinery
28	Mining and quarrying
29	Food and tobacco
30	Paper pulp and printing
31	Wood and wood products
32	Construction
33	Textile and leather

34	Non-specified
35	Transport
36	Residential
37	Commercial and public services
38	Agriculture / forestry
39	Fishing
40	Non-specified
41	Non-energy use

Serial number	Column description
1	Coal
2	Crude oil
3	Oil products
4	Natural gas
5	Hydro
6	Wind, solar, etc.
7	Biofuels and waste
8	Electricity
9	Heat
10	Total

Appendix 11: World market prices for energy carriers

Serial number	Row description
1	World market price: crude oil, average (USD/bbl)
2	World market price: Coal, Australian (USD/mt)
3	World market price: Natural gas, Europe (USD/mmbtu)

Appendix 12: Energy prices

Serial number	Row description
1	Prices for households: hard coal (KZT/t)
2	Prices for households: oil products (gasoline, diesel weighted, KZT/litre)
3	Prices for households: natural gas (KZT/m3)
4	Prices for households: electricity (KZT/100 kWh)

5	Prices for households: heat (KZT/Gcal)
6	Prices for industrial consumers: coal (KZT/t)
7	Prices for industrial consumers: oil products (diesel KZT/t)
8	Prices for industrial consumers: natural gas (KZT/1,000 m3)
9	Prices for industrial consumers: electricity (KZT/1,000 kWh)

Appendix 13: Average energy price indices by economic sectors

Serial number	Row description
1	Iron and steel
2	Chemical and petrochemical
3	Non-ferrous metals
4	Non-metallic minerals
5	Transport equipment
6	Machinery
7	Mining and quarrying
8	Food and tobacco
9	Paper, pulp, printing
10	Wood and wood products
11	Construction
12	Textile, leather
13	Non-specified
14	Transport
15	Residential
16	Commercial and public services
17	Agriculture, forestry
18	Fishing
19	Non-specified
20	Non-energy use

Appendix 14: CO_2 emissions by sectors

Serial number	Row description
1	Iron and steel
2	Chemical and petrochemical
3	Non-ferrous metals
4	Non-metallic minerals
5	Transport equipment
6	Machinery
7	Mining and quarrying
8	Food and tobacco
9	Paper, pulp, printing
10	Wood and wood products
11	Construction
12	Textile, leather
13	Non-specified
14	Transport
15	Residential
16	Commercial and public services
17	Agriculture, forestry
18	Fishing
19	Non-specified
20	Non-energy use

Appendix 15: Implied emission factors

Serial number	Row description
1	Public electricity and heat production
2	Petroleum refining
3	Manufacture of solid fuels and other energy industries
4	Manufacturing industries and construction
5	Iron and steel
6	Chemicals
7	Non-ferrous metals
8	Non-metallic minerals
9	Food processing, beverages and tobacco

10	Pulp, paper and print
11	Transport
12	Residential
13	Commercial and public services
14	Agriculture/forestry/fishing
Serial number	Column description
1	Coal
2	Crude oil
3	Oil products
4	Natural gas

Appendix 16: Allocation of the 19 classification to the 72 classification of economic sectors

19 Classification of economic sectors		72 Classification of economic sectors	
Serial number		Serial number	Description
17	Agriculture / forestry	1	Plant and animal husbandry, hunting and provision of services in these areas
		2	Forestry and logging
18	Fishing	3	Fishery and aquaculture
7	Mining and quarrying	4	Coal and lignite production
		5	Extraction of crude oil and natural gas
		6	Production of metal ores
		7	Other sectors of the mining industry
		8	Technical services in the mining industry
8	Food and tobacco	9	Food production
		10	Manufacture of beverages
		11	Manufacture of tobacco products
12	Textile and leather	12	Manufacture of textiles
		13	Manufacture of clothing
		14	Manufacture of leather and related products
10	Wood and wood products	15	Manufacture of wood and cork, except furniture; manufacture of articles of straw and plaiting material
9	Paper pulp and printing	16	Manufacture of paper and paper products
		17	Printing and reproduction of recorded materials
-	-	18	Manufacture of coke oven products

–	–	19	Production of oil refining products
2	Chemical and petrochemical	20	Manufacture of chemical products
		21	Manufacture of basic pharmaceutical products
13	Non-specified	22	Manufacture of rubber and plastic products
4	Non-metallic minerals	23	Manufacture of other non-metallic mineral products
1	Iron and steel	24	Metallurgical industry
3	Non-ferrous metals		
13	Non-specified	25	Manufacture of fabricated metal products, except machinery and equipment
		26	Development of computers, electronic and optical products
		27	Manufacture of electrical equipment
6	Machinery	28	Manufacture of machinery and equipment not included in other categories
5	Transport equipment	29	Manufacture of motor vehicles, trailers and semi-trailers
		30	Manufacture of other vehicles
13	Non-specified	31	Manufacture of furniture
		32	Manufacture of other finished products
		33	Repair and installation of machinery and equipment
		34	Electricity, gas, steam and air conditioning
		35	Water supply; sewerage, waste management and remediation activities
11	Construction	36	Construction
16	Commercial and public services	37	Wholesale and retail trade and repair of motor vehicles and motorcycles
		38	Wholesale trade, except of motor vehicles and motorcycles
13	Non-specified	39	Retail trade, except of motor vehicles and motorcycles
14	Transport	40	Land transport and pipeline transportation
		41	Water transport
		42	Commercial air traffic
		43	Warehousing and support activities for transportation
16	Commercial and public services	44	Postal and courier services
		45	Accommodation services
		46	Food and beverage services
		47	Information services
		48	Communication services
		49	Excluding financial services, insurance and pension funds

		50	Insurance, reinsurance and pension fund activities, except for compulsory social insurance
		51	Support activities for financing and insurance services
		52	Real estate transactions
		53	Activity in the field of law and accounting
		54	Parent company activity; management consulting
		55	Activities in the field of architecture, engineering research, technical testing and analysis
		56	Research and development
		57	Research of advertising activity and market conditions
		58	Other professional, scientific and technical activities
		59	Veterinary activity
		60	Leasing, renting, leasing
		61	Employment
		62	Activities of tour operators, travel agents and other service providers in the field of tourism
		63	Security and inquiry services
		64	Activity in the area of maintenance of buildings and territories
		65	Activity in the field of administrative, management, economic and other support services
		66	Public administration and defense; compulsory social security
		67	Education
		68	Activity in the field of health care
		69	Social services
		70	Art, entertainment and recreation
		71	Other services
		72	Household service that hires a domestic worker and produces goods and services for personal use
15	Residential	–	–

Appendix 17: Allocation of the 21 classification to the 72 classification of economic sectors

21 Classification of economic sectors		72 Classification of economic sectors	
Serial number	Description	Serial number	Description
1	Agriculture, forestry and fishing	1	Plant and animal husbandry, hunting and provision of services in these areas
		2	Forestry and logging
		3	Fishery and aquaculture
2	Mining and quarrying	4	Coal and lignite production
		5	Extraction of crude oil and natural gas
		6	Production of metal ores
		7	Other sectors of the mining industry
		8	Technical services in the mining industry
3	Manufacturing	9	Food production
		10	Manufacture of beverages
		11	Manufacture of tobacco products
		12	Manufacture of textiles
		13	Manufacture of clothing
		14	Manufacture of leather and related products
		15	Manufacture of wood and cork, except furniture; manufacture of articles of straw and plaiting material
		16	Manufacture of paper and paper products
		17	Printing and reproduction of recorded materials
		18	Manufacture of coke oven products
		19	Production of oil refining products
		20	Manufacture of chemical products
		21	Manufacture of basic pharmaceutical products
		22	Manufacture of rubber and plastic products
		23	Manufacture of other non-metallic mineral products
		24	Metallurgical industry
		25	Manufacture of fabricated metal products, except machinery and equipment
		26	Development of computers, electronic and optical products
		27	Manufacture of electrical equipment
		28	Manufacture of machinery and equipment not included in other categories
		29	Manufacture of motor vehicles, trailers and semi-trailers

		30	Manufacture of other vehicles
		31	Manufacture of furniture
		32	Manufacture of other finished products
		33	Repair and installation of machinery and equipment
4	Electricity, gas, steam and air conditioning supply	34	Electricity, gas, steam and air conditioning
5	Water supply; sewerage, waste management and remediation activities	35	Water supply; sewerage, waste management and remediation activities
6	Construction	36	Construction
7	Wholesale and retail trade; repair of motor vehicles and motorcycles	37	Wholesale and retail trade and repair of motor vehicles and motorcycles
		38	Wholesale trade, except of motor vehicles and motorcycles
		39	Retail trade, except of motor vehicles and motorcycles
8	Transportation and storage	40	Land transport and pipeline transportation
		41	Water transport
		42	Commercial air traffic
		43	Warehousing and support activities for transportation
		44	Postal and courier services
9	Accommodation and food service activities	45	Accommodation services
		46	Food and beverage services
10	Information and communication	47	Information services
		48	Communication services
11	Financial and insurance activities	49	Excluding financial services, insurance and pension funds
		50	Insurance, reinsurance and pension fund activities, except for compulsory social insurance
		51	Support activities for financing and insurance services
12	Real estate activities	52	Real estate transactions
13	Professional, scientific and technical activities	53	Activity in the field of law and accounting
		54	Parent company activity; management consulting
		55	Activities in the field of architecture, engineering research, technical testing and analysis
		56	Research and development
		57	Research of advertising activity and market conditions
		58	Other professional, scientific and technical activities
		59	Veterinary activity
14		60	Leasing, renting, leasing

	Administrative and support service activities	61	Employment
		62	Activities of tour operators, travel agents and other service providers in the field of tourism
		63	Security and inquiry services
		64	Activity in the area of maintenance of buildings and territories
		65	Activity in the field of administrative, management, economic and other support services
15	Public administration and defense; compulsory social security	66	Public administration and defense; compulsory social security
16	Education	67	Education
17	Human health and social work activities	68	Activity in the field of health care
		69	Social services
18	Arts, entertainment and recreation	70	Art, entertainment and recreation
19	Other service activities	71	Other services
20	Activities of households employing domestic workers and producing goods and services for own consumption	72	Household service that hires a domestic worker and produces goods and services for personal use
21	Activities of extraterritorial organizations and bodies		Plant and animal husbandry, hunting and provision of services in these areas

Appendix 18: Allocation of the 72 classification to the 68 classification economic sectors

72 Classification of economic sectors		68 Classification of economic sectors	
Serial number	Description	Serial number	Description
1	Plant and animal husbandry, hunting and provision of services in these areas	1	Agriculture, hunting products and related services
2	Forestry and logging	2	Forestry, logging products and related services
3	Fishery and aquaculture	3	Fish and other fishing products; aquaculture; auxiliary fishing services
4	Coal and lignite production	4	Coal and lignite
5	Extraction of crude oil and natural gas	5	Crude oil
		6	Natural gas in a liquid or gaseous state
6	Production of metal ores	7	Iron ores
		8	Non-ferrous metals
7	Other sectors of the mining industry	9	Products of the mining industry
8	Technical services in the mining industry	10	Support services to the mining industry

9	Food production	11	Food products, beverages
10	Manufacture of beverages		
11	Manufacture of tobacco products	12	Tobacco products
12	Manufacture of textiles	13	Textiles
13	Manufacture of clothing	14	Wearing apparel
14	Manufacture of leather and related products	15	Leather and related products
15	Manufacture of wood and cork, except furniture; manufacture of articles of straw and plaiting material	16	Wood and articles of wood and cork (except furniture), articles of straw and plaiting materials
16	Manufacture of paper and paper products	17	Paper and paper products
17	Printing and reproduction of recorded materials	18	Printing and reproduction services
18	Manufacture of coke oven products	19	Products of coke oven
19	Production of oil refining products	20	Oil refining products
20	Manufacture of chemical products	21	Chemicals and chemical products
21	Manufacture of basic pharmaceutical products	22	Pharmaceutical products and basic pharmaceuticals
22	Manufacture of rubber and plastic products	23	Rubber and plastic products
23	Manufacture of other non-metallic mineral products	24	Other non-metallic mineral products
24	Metallurgical industry	25	Basic ferrous metals: iron, cast iron, steel and ferroalloys
		26	Pipes of various diameters, hollow profiles and fittings for stainless steel pipes
		27	Other steel products of primary processing
		28	Basic precious metals and other non-ferrous metals
		29	Foundry services
25	Manufacture of fabricated metal products, except machinery and equipment	30	Finished metal products, except machinery and equipment
26	Development of computers, electronic and optical products	31	Computers, electronics and optical products
27	Manufacture of electrical equipment	32	Electrical equipment
28	Manufacture of machinery and equipment not included in other categories	33	Machinery and equipment nec
29	Manufacture of motor vehicles, trailers and semi-trailers	34	Cars, trailers and semitrailers
30	Manufacture of other vehicles	35	Other transport equipment
31	Manufacture of furniture	36	Furniture
32	Manufacture of other finished products	37	Other finished goods

33	Repair and installation of machinery and equipment	38	Repair and installation services of machinery and equipment
34	Electricity, gas, steam and air conditioning	39	Power generation and distribution services
		40	Flammable gas; gas distribution services for gas pipelines
		41	Refrigerated steam and air conditioning services
35	Water supply; sewerage, waste management and remediation activities	42	Water supply; sewerage, waste management services
36	Construction	43	Construction works
37	Wholesale and retail trade and repair of motor vehicles and motorcycles	44	Wholesale and retail services; repair services of motor vehicles and motorcycles
38	Wholesale trade, except of motor vehicles and motorcycles	45	Wholesale trade services, except of motor vehicles and motorcycles
39	Retail trade, except of motor vehicles and motorcycles	46	Retail services, except motor vehicles and motorcycles
40	Land transport and pipeline transportation	47	Land transport services and pipelines
41	Water transport	48	Water transport services
42	Commercial air traffic	49	Air transport services
43	Warehousing and support activities for transportation	50	Storage services and ancillary transportation services
44	Postal and courier services	51	Postal and courier services
45	Accommodation services	52	Accommodation services
46	Food and beverage services	53	Food and beverage service activities
47	Information services	54	Information services
48	Communication services	55	Communication services
49	Excluding financial services, insurance and pension funds	56	Except financial services, insurance and pension services
50	Insurance, reinsurance and pension fund activities, except for compulsory social insurance	57	Insurance, reinsurance and pension services, except compulsory social security services
51	Support activities for financing and insurance services	58	Support services for financial intermediation and insurance
52	Real estate transactions	59	Real estate services
53	Activity in the field of law and accounting	60	Professional, scientific and technical services
54	Parent company activity; management consulting		
55	Activities in the field of architecture, engineering research, technical testing and analysis		
56	Research and development		
57	Research of advertising activity and market conditions		

58	Other professional, scientific and technical activities		
59	Veterinary activity		
60	Leasing, renting, leasing	61	Activities in the field of administrative and support services
61	Employment		
62	Activities of tour operators, travel agents and other service providers in the field of tourism		
63	Security and inquiry services		
64	Activity in the area of maintenance of buildings and territories		
65	Activity in the field of administrative, management, economic and other support services		
66	Public administration and defense; compulsory social security	62	Public administration and defense services; compulsory social security services
67	Education	63	Education services
68	Activity in the field of health care	64	Health services
69	Social services	65	Social services
70	Art, entertainment and recreation	66	Arts, entertainment and recreation services
71	Other services	67	Other services
72	Household service that hires a domestic worker and produces goods and services for personal use	68	Services of households hiring domestic workers and the production of goods and services for own use

Appendix 19: NUTS1 level

Serial number	Row description
1	Kazakhstan
2	Akmola
3	Aktobe
4	Almaty
5	Atyrau
6	West KZ
7	Jambyl
8	Karaganda
9	Kostanay
10	Kyzylorda
11	Mangystau

12	Pavlodar
13	North KZ
14	South KZ
15	East KZ
16	Astana (Nur-Sultan)
17	Almaty City
18	Abai
19	Zhetysu
20	Ulytau
21	Shymkent

Appendix 20: Gross regional product by economic sectors

Serial number	Row description
1	Total
2	Agriculture, forestry, fishing
3	Mining, quarrying
4	Manufacturing
5	Electricity, gas, steam, air conditioning supply
6	Water supply; sewerage, waste management, remediation activities
7	Construction
8	Wholesale, retail trade; repair of motor vehicles, motorcycles
9	Transportation, storage
10	Accommodation, food service activities
11	Information and communication
12	Financial, insurance activities
13	Real estate activities
14	Professional, scientific, technical activities
15	Administrative, support service activities
16	Public administration, defense; compulsory social security
17	Education
18	Human health, social work activities
19	Arts, entertainment, recreation
20	Other service activities
21	Net taxes