E3.dz: An energy-economy model for Algeria

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LIST OF ABBREVIATIONS

BAU	Business as usual
CGE	Computable General Equilibrium models
CO2	Carbon dioxide
CREAD	Centre for Applied Economic Research for Development (Centre de recherche en économie appliquée pour le développement)
CSP	Concentrated solar power
DZD	Algerian Dinar
EE	Energy efficiency
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
GW	Gigawatt
GWS	Institute of Economic Structures Research (Gesellschaft für Wirtschaftliche Strukturforschung)
IEA	International Energy Agency
IOT	Input-output table
ISMMEE	Steel, metal, mechanical, electrical and electronic industries
JIT	Just In Time
MBtu	Million British thermal units
MEM	Energy Ministry of Algeria (Ministère de l'Énergie)
MENA	Middle East and North Africa
OLS	Ordinary least squares
ONS	National statistical office of Algeria (Office National des Statistiques)
PV	Photovoltaic
RE	Renewable energy
RMSE	Root-mean-square error
SCEA	Algerian economic accounts system (système des comptes économiques algériens)
SNA	System of national accounts
t	Ton

toe	Ton of oil equivalent
UN	United Nations
UNDP	United Nations Development Programme
USD	US Dollar
VBA	Visual Basic for Applications

SUMMARY

The Algerian economy remains heavily dependent on hydrocarbons, as the latest economic update from the World Bank (2019a) for Algeria states. The costs of social programs for poverty alleviation, improvement of the educational system, as well as subsidies still in existence, increasingly burden the public budget in times of lower oil and gas prices. Against this background Algeria's energy transition towards electricity from renewable energy and increased efficiency in buildings and industry is expected to exhibit various benefits. To detect the full scope of economic effects, the mere calculation of direct and indirect employment from renewable energy and energy efficiency increases (Lehr and Banning 2018) can only be a first step. Therefore, a more comprehensive assessment method, i.e. a full economic (and energy) model with feedback loops and second round effects has been developed.

For Algeria as a resource-based economy, a macro-econometric model with a flexible approach seems to be more suitable than a CGE model with its rigid theory based framework. The result is the model e3.dz. It is a dynamic long-term simulation model to describe socio-economic impacts of (energy) policies. Parameters are econometrically estimated. The model is based on data from 2000 until 2017 and projects the development until 2050. A reference simulation reflects the continuation of the economy under a development of the determining exogenous factors borrowed from international sources, such as oil price development by IEA etc. To analyze the effects of energy policies – or any other policy – these policies have to be translated into changes of economic quantities and model variables. The changes result in deviations of core economic variables such as GDP, employment or changes of production in certain economic sectors. The deviations can be interpreted as the result of the respective policies. e3.dz hence can be used as a tool for the impact analysis of the respective policy. Data are the most important input for data-based policy analysis. e3.dz rests to a large extent on Algerian data and national statistics.

e3.dz can be used to simulate the effects of different pathways for the energy transition foreseen by the Algerian government. To do so, scenarios including the energy transition have to be compared to scenarios without any structural changes in the energy system. A scenario is a consistent set of assumptions about the future development of certain characteristic model quantities. For instance, an energy transition scenario will be built from assumptions on renewable energy capacities installed, energy efficiency changes, prices of energy etc.

SOMMAIRE

L'économie algérienne reste fortement dépendante des hydrocarbures, comme l'indique la dernière mise à jour économique de la Banque mondiale (2019a) pour l'Algérie. Les coûts des programmes sociaux de lutte contre la pauvreté et d'amélioration du système éducatif, ainsi que les subventions encore en place, pèsent de plus en plus lourd sur le budget public, et ce en période de baisse des prix du pétrole et du gaz. Dans ce con-texte, la transition énergétique de l'Algérie vers l'électricité à partir d'énergies renouve-lables et l'amélioration de l'efficacité énergétique des bâtiments et de l'industrie devrait présenter divers avantages. Pour détecter toute l'ampleur des effets économiques, le simple calcul de l'emploi direct et indirect lié aux énergies renouvelables et à l'augmentation de l'efficacité énergétique (Lehr et Banning, 2018) ne peut être qu'un premier pas. En conséquence, une méthode d'évaluation plus complète, c'est-à-dire un modèle économique (et énergétique) complet, tenant compte des boucles de rétroaction et des effets secondaires, a été élaborée.

Pour l'Algérie, en tant qu'économie basée sur les ressources, un modèle macro-économétrique selon une approche flexible semble plus approprié qu'un modèle CGE au cadre théorique rigide. Le résultat est le modèle e3.dz. Il s'agit d'un modèle de simu-lation dynamique à long terme pour décrire les impacts socio-économiques des politiques (énergétiques). Les paramètres sont estimés en termes économétriques. Basé sur des données de 2000 à 2017, le modèle projette le développement jusqu'en 2050. Une simulation de référence reflète l'évolution de l'économie en fonction du développe-ment de facteurs exogènes déterminants, provenant de sources internationales, tels que l'évolution du prix du pétrole fixé par l'AIE, etc. Pour analyser les effets des poli-tiques énergétiques – ou de toute autre politique – ces politiques doivent se traduire par des changements de quantités économiques et de variables modèles. Ces change-ments se traduisent par des déviations de variables économiques fondamentales telles que le PIB, l'emploi ou les variations de la production dans certains secteurs écono-miques. Les écarts peuvent être interprétés comme le résultat des politiques prospec-tives. e3.dz peut donc être utilisé comme un outil pour l'analyse d'impact de la politique prospective. Bien évidemment, les données sont les apports les plus importants pour l'analyse des politiques sur la base de données. e3.dz est fondé dans une large mesure sur les données algériennes et les statistiques nationales.

e3.dz peut être utilisé pour simuler les effets des différentes trajectoires de transition énergétique prévues par le Gouvernement algérien. Pour ce faire, les scénarios in-cluant la transition énergétique doivent être comparés à des scénarios sans aucun changement structurel dans le système énergétique. Un scénario est un ensemble cohérent d'hypothèses sur l'évolution future de certaines quantités caractéristiques du modèle. Par exemple, un scénario de transition énergétique sera-t-il construit à partir d'hypothèses sur les capacités en matière d'énergie renouvelable installées, les évolu-tions en matière d'efficacité énergétique, les prix de l'énergie, etc..

1 INTRODUCTION

1.1 TASK DEFINITION: ALGERIAN ENERGY-ECONOMY MODEL WITH SCENARIOS FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY

The Algerian economy remains heavily dependent on hydrocarbons, as the latest economic update from the World Bank (2019a) for Algeria states. The report describes the status as of spring 2020. The model has since been updated but the model structure is almost completely unchanged. The costs of social programs for poverty alleviation, improvement of the educational system, as well as subsidies still in existence, increasingly burden the public budget in times of lower oil and gas prices. The World Bank (2019b) states that Algeria's hydrocarbon revenues have halved in recent years, also due to decreasing production and rising domestic demand.

Against this background Algeria's energy transition towards electricity from renewable energy and increased efficiency in buildings and industry is expected to exhibit various benefits. GWS has a long-standing experience in modelling employment from renewable energy (RE) and energy efficiency (EE) in the MENA region, the most recent experiences being Lebanon (UNDP 2019) and Algeria (Lehr & Banning 2018). In these models, however, the feedback loops to the overall economic development are not included.

To detect the full scope of economic effects, the mere calculation of direct and indirect employment from renewable energy and energy efficiency increases does not suffice. A more comprehensive assessment method, i.e. a full economic (and energy) model with feedback loops and second round effects, is needed. This approach answers comprehensively the question of overall economic effects of a transition towards a renewable energy-based efficient energy system. This tool, once established, can be used for further analyses also in other economic sectors, such as tourism, health, or different industries.

Such a full economy-energy model has to combine two sets of data, macroeconomic and – if possible – sector and industry data in monetary terms on the one hand and energy data in physical terms on the other hand. Energy prices are a major link, as they translate energy demand and energy supply volumes in monetary terms. For the economy and for energy supply, consumption, and transformation, international accounting systems have been developed over the last decades. Macroeconomic development is described and structured in the system of national accounts (SNA), energy data in energy balances.

This report describes the philosophy and structure of such a full economy-energy model for Algeria. Such models are often referred to as "economy-energy-environment models", hence the abbreviation e3. In GWS' family of country models the international country code (ISO-3166) completes the model's name to e3.dz. The modelling approach is presented in section 1.2. Different scenarios with regard to renewable energy deployment and energy efficiency improvement have been developed.

In appendices, central data for the model are listed (section 4). In addition, the model description with all definitory equations and estimation functions is included (section 5). Important steps for using the model are explained in the user manual (section 6). Moreover, the model is also described from a technical point of view (section 7).

1.2 MODELLING APPROACH OF E3.DZ

Quantitative economic models are classified with respect to the time horizon (short-term, i.e. business-cycle, vs. long-term), their time dependence (static vs. dynamic), level of analysis (micro, meso, macro), economic theory, the use of econometric methods and application (forecast vs. impact analysis).

Business cycle models often use quarterly data and do not reflect long-term structural adjustments. Therefore, they are of limited use for the analysis of the transitions in the economy-energy system.

Static models consistently describe the economy at a certain point in time, e.g. today. By altering an element of the model (e.g. the tax rate), the response to this change is simulated. Effects can be compared as "before" and "after" the change, often referred to as comparative-static analysis. This analysis is useful as a first estimate of the possible size of effects. The adjustment process from one state of affairs to the other can be observed and analyzed using dynamic models. They account for time-dependence, transition effects and development of the economic quantities.

Dynamic models apply econometric methods or make use of assumptions and axioms from economic theory to project agents' behavior to the future. Econometric methods use regressions over time series data to extract past behavior and its influencing variables. The estimates include elasticities between demand and prices, household consumption and economic development or exports and international price development. The economic input-output table and the system of national accounts provide the consistency conditions. The resulting macro-econometric models are based on the post-Keynesian theory that emphasizes the demand side, with both market sides playing an important role, unlike simple input-output approaches. Markets are usually not cleared, as the economy is assumed not to be in equilibrium. Involuntary unemployment and idle capital are included. Imbalances between supply and demand are more likely to be offset by demand-driven rather than price effects.

If time series are not available, economic theory and axioms can be used. Again, input-output tables and the system of national accounts are at the core of these so-called computable general equilibrium models. Time is not explicit in these models. Households and businesses are assumed to maximize their benefits and profits. The markets of different goods are cleared (are in an equilibrium), i.e. supply and demand balance and economic resources are fully utilized. Involuntary unemployment is not possible in the standard case. Higher demand for a good (for example renewable energy required for the energy transition) leads to higher prices of primary factors (energy, capital, labor) and a reallocation of resources away from the optimal. Often, the models used in policy consulting break away from rigid theories to more adequately reflect reality.

Another relevant characteristic is the scale of data and analysis. Micro models use surveys and examine the behavior of individuals or household types whereas macro models analyze the economy as a whole based on macro data such as GDP, consumption and investment. Meso models are often macro models with more industry detail usually given by IO tables. Econometric models and CGE models operate on this scale. For Algeria as an economy, which is still dominated largely by the public oil and gas industry, a currently otherwise low diversification of the economy and subsidized pricing in some sectors, a macro-econometric model seems to be more suitable than a CGE model.

To model the interaction between energy and the economy in a long-term perspective, the energy balance needs to be fully integrated into the economic model. Changes in the technology mix will then lead to changes in the economic quantities and vice versa. Energy demand by fuel needs to be separately estimated, because energy consumption also depends on energy efficiency, technological progress, consumer preferences and the structure of the economy (CREAD 2019). In addition, Dilaver and Hunt (2011) found effects of unobservable factors and suggest certain estimation methods (see also chapter 1.3).

GWS has developed a national economy-energy-environment model for Germany (PANTA RHEI) over the last 25 years, which combines economic data including IO tables and energy balance data. It covers and links the German economy with the "energy world" and does so in great detail with regard to national accounts, industries, energy balances and energy carriers. It has been applied in various projects to develop and evaluate policy strategies on national, industry and regional level (Lutz et al. 2018, Lehr et al. 2015). On a global scale, GWS' GINFORS_E model extends the same model philosophy to more than 50 countries, linked by bilateral trade flows for 25 product groups (Asselin-Miller et al. 2017). The country models in this system are less detailed than in PANTA RHEI, but capture industrial structures, demand shifts and changes in the energy system as well. The central parts of the economic part of the model are the input-output table and national accounts (macroeconomic data) plus labor market (see Figure 1). Energy balances, which include energy supply, transformation and (final) energy demand, are at the center of the energy part. CO2 emissions can be calculated quite easily using fixed emission factors. Economy and energy are linked by energy volumes and prices, which depend on unit costs.

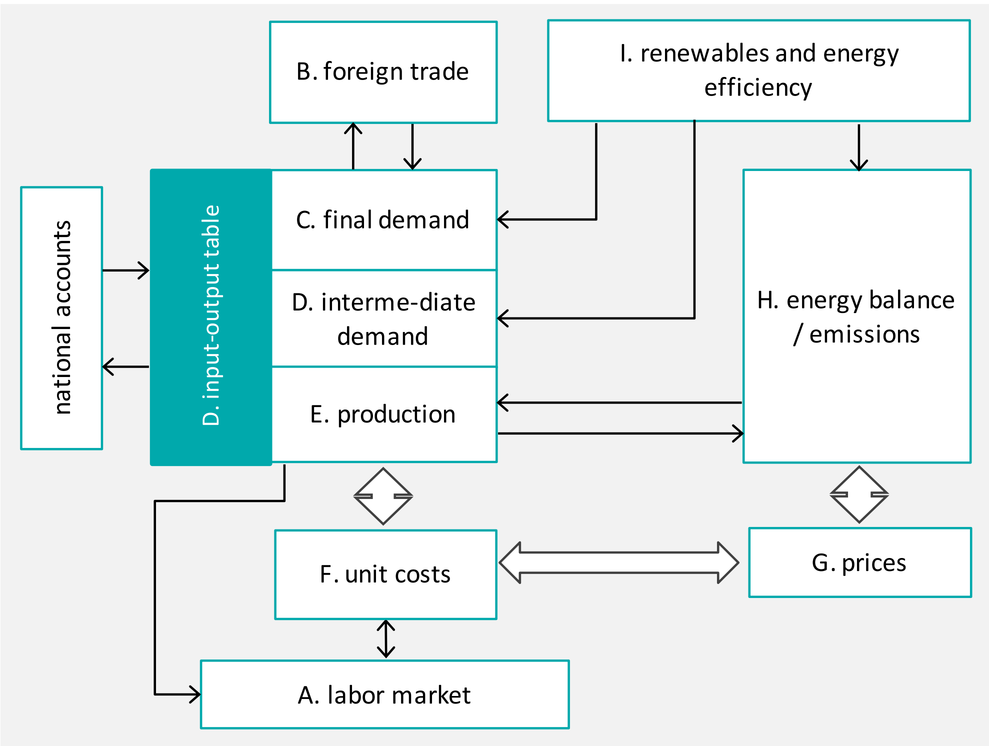

Figure 1: Energy-economy country model

Source: own figure

During the project, national models of GINFORS_E have been the starting point. This prototype has been filled with national Algerian data. The model philosophy had to be partly adjusted. The large part of hydrocarbon returns in GDP needs special attention and eludes the modelling approaches of economies that are not resource-based. The most important parts have been endogenized during the project. This model refinement has been done in close discussion and cooperation with the Algerian partners and the GIZ.

The result is the model e3.dz. It is a dynamic long-term simulation model to describe socio-economic impacts of (energy) policies. Parameters are econometrically estimated. The model is based on data from 2000 until 2017 and projects the development until 2050. A reference simulation reflects the continuation of the economy under a development of the determining exogenous factors borrowed from international sources, such as oil price development by IEA etc. To analyze the effects of energy policies – or any other policy – these policies have to be translated into changes of economic quantities and model variables. The changes result in deviations of core economic variables such as GDP, employment or changes of production in certain economic sectors. The deviations can be interpreted as the result of the respective policies. e3.dz hence can be used as a tool for the impact analysis of the respective policy.

Data are the most important input for data-based policy analysis. e3.dz rests to a large extent on Algerian data and national statistics. This section describes the data used in the different modules depicted in Figure 1. If the data enter the model unchanged, only the sources are quoted. If they have been altered, the data used are given in Appendix A.

For the labor market (box A of Figure 1), data on the population or on the population of working age (age groups 15 to 64 years) are necessary, which are provided by the National Statistical Office of Algeria (ONS). Other macro variables such as labor force, employment and unemployment as well as wages are also reported by ONS. In addition, employment is broken down according to the sectors agriculture, construction, industry and services (also provided by ONS). A more detailed disaggregation into different economic activities in industry is not available in national labor statistics.

The foreign trade module (box B of Figure 1) requires data for exchange rate (DZD/USD), imports and exports (also provided by ONS). The data for the world trade volume originate from the World Bank (2019c).

The final demand module (box C of Figure 1) requires data on gross domestic product, household consumption expenditures, government consumption expenditures, changes in inventories, gross fixed capital formation, and exports. ONS provides time series for these data.

The input-output table (IOT, box D of Figure 1) is one of the core structures of the model as described above. ONS publishes input-output tables for Algeria. Since this IOT is not symmetrical (18 supplying sectors vs. 19 receiving sectors), one column is eliminated by merging columns 15 and 16. Accordingly, column and row 17 become 16, 18 become 17 and 19 become 18 (see Figure 9 to Figure 11 in section 4.1). e3.dz currently uses the IOT for the year 2015 as applied in Lehr and Banning (2018). More recent updates are available, but consistency with authors' earlier estimates seems to be more relevant. The 2015 structure is maintained over time.

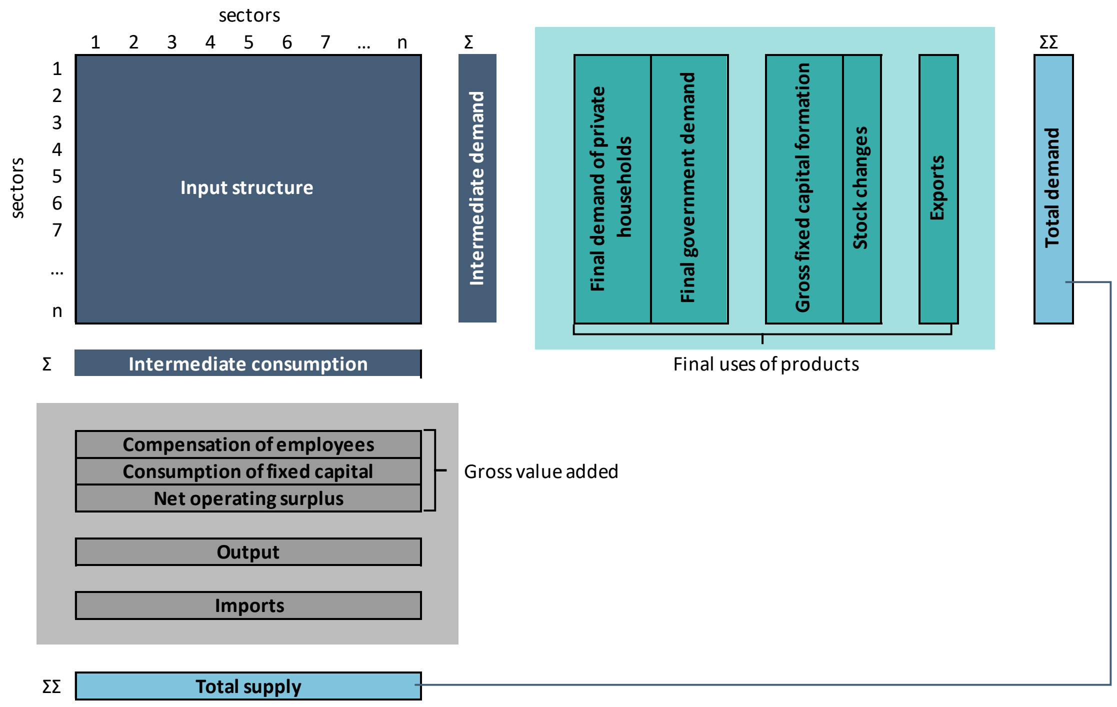

Figure 2: Schematic representation of an IOT

Source: own figure

The IOT does not include value added from non-productive services, which is due to different concepts of national accounts: While the demand components are based on the GDP concept, the IOT follows the Algerian SCEA concept ("système des comptes économiques algériens"). The link between these two concepts is as follows:

Household consumption expenditures
+ Government consumption expenditures
+ Gross fixed capital formation
+ Exports
- Imports
= Gross domestic product (GDP) (UN SNA concept) ("le PIB")
- value added of non-productive services
+ purchases of non-productive services
+/- adjustment for imputed banking services
= Gross domestic production (SCEA concept) ("la PIB")

For consumption expenditures of real estate affairs and of financial institutions, the data are extracted from input-output tables and added over the sectors.

Box E contains the production equation, one of the core equations linking the intermediate production structure (Leontief inverse) of the first quadrant of the IOT with the final demand in the third quadrant. No additional data are required for this step.

For unit costs (box F of Figure 1), there are no past data. They are calculated using the IOT for the forecast period in the model.

For the world market prices for coal, gas, and crude oil (box G of Figure 1), data from BP (2019) are used. The consumer prices for electricity and gas were provided by the Energy Ministry of Algeria. For oil products, consumer prices come from the IEA data-base (see section 4.2).

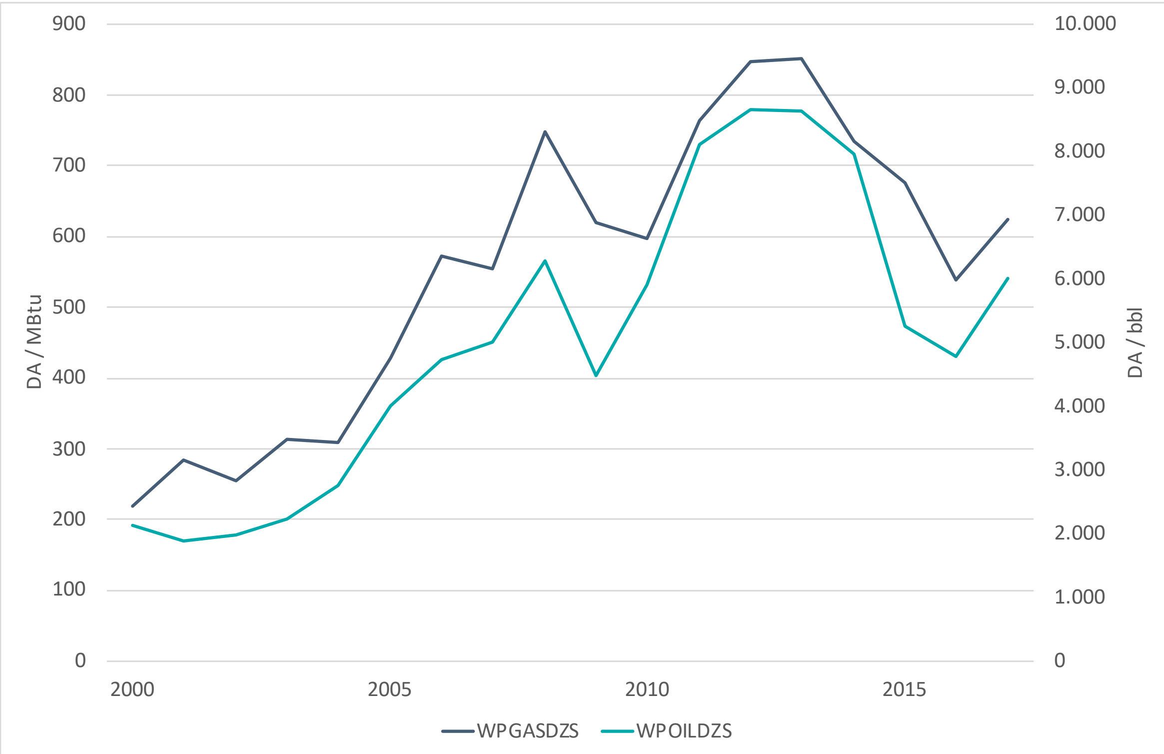

Figure 3: World market prices for natural gas and crude oil

Source: BP 2019

In the energy part of the model (box H of Figure 1), the data are based on the energy balances of the Energy Ministry of Algeria (Ministère de l'Énergie (MEM), several years). The original energy balance 2A has 47 rows, in this model it is used in condensed form. The differentiation in the transformation sector as well as the subdivision of transport into modes are neglected, so that the energy balance implemented in the model has 30 rows (see Figure 12 in section 4.3). The various energy sources are condensed to five columns. Since the energy balances before 2014 had a different structure, they were transformed and missing data was imputed by the calculation with constant shares.

For past CO_2 emissions of Algeria, data from the IEA (2019a) were used, which are differentiated according to the energy sources coal, oil, and gas. The following constant emission factors from the literature are used for the projection:

	Emission factor [t CO_2 / toe]
Coal	4.1
Oil	3.1
Natural gas	2.4

Table 1: Emission factors

Source: Global Chance 2019

Box I comprises the renewable energy and energy efficiency module. No assumptions are made regarding past energy efficiency development, specific modelling of energy efficiency starts with the simulation period. Renewable energy installations until 2018 have been collected in Lehr and Banning (2018) (Table 2).

Sector		2014	2015	2016	2017
Newly installed, MW		11	48	170	125
PV	5-10 MW	1	28	30	2
	> 10 MW	0	20	140	123
Wind		10	0	0	0
Cumulated, MW					
PV	5-10 MW	1	29	59	61
	> 10 MW	0	20	160	283
Wind		10	10	10	10

Table 2: Renewable energy capacities installed

Source: Lehr and Banning 2018

1.3 ESTIMATION OF PARAMETERS

All behavioral parameters of the model are estimated econometrically, and different specifications of the functions are tested against each other, which gives the model an empirical validation. When selecting alternative estimation approaches, a priori information on signs and magnitudes of the coefficients to be estimated was first used: Economically nonsensical estimation results (e.g. wrong sign of a coefficient) were discarded. An additional confirmation of the model structure as a whole is given by the convergence property of the solution, which has to be fulfilled on a yearly basis. In order to achieve this, various specifications were tested in the model context. Only if the specifications also lead to comprehensible results in the overall model, they are finally selected. The model should also reflect certain expectations identified in other detailed studies (macroeconomic projections; long-term energy scenarios with bottom-up models). This is particularly important because of the often short time series that are available for key parameters. Data have been available since 1984 for only a few macroeconomic variables. For the structural parameters of the input-output tables, the time series date back to 1999. Energy balances have changed again and again regarding their form, especially in the final energy consumption of industry. The same sector structure has existed since 2014. The energy balances from previous years have been adjusted accordingly. The last complete energy balance is available for 2006. For the years before, there are only data for individual lines of the energy balance with which energy balances were reconstructed. For most functional relationships, the estimation period is limited to the years 2000 to 2015/17. In view of the long-term modelling horizon up to 2050, this means that particular attention must be paid to the stability of the overall model.

Against this background the estimates were carried out using the Ordinary Least Squares (OLS) method. OLS yields a linear regression model by minimizing the sum of squared residuals, i.e. the difference between actual and predicted data points. Central statistical test measures were included in the evaluation. 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 R2, 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 R2, the higher the explanatory value of the model is. Different equations can thus be compared using the R2 (or in the case of different numbers of regressors the adjusted R2, which controls for the positive effect of additional regressors by imposing a penalty on the respective equation). Similar comparisons can be made using the root-mean-square error (RMSE), measuring the deviations of all predicted values from actual data points.

ILLUSTRATIVE EXAMPLES

All approaches for the estimations are listed in section 5. Different variations for them can be applied: For example, the estimation period can be changed (if the data are available) or the regressors can be varied using lags.

Figure 4 shows the example of estimating current year's governmental expenditures by using last year's total GDP (each in constant prices). Both the intercept and the explanatory variable show a highly significant t-statistic (-3.1 and 11.6 respectively), thus the probability that they do not influence the dependent variable is low (about 0.001% and <0.0000001%, respectively, assuming a standard normal distribution). The R2 is rather high with around 90% of the variation explained by the explanatory variable. Overall the presented linear model seems to provide a good estimation. Interpretation is that there is a rather independent amount of governmental consumption, represented by the intercept. Besides that, expenditure scale with the total GDP of the previous year in constant prices, thus expenditure rises after prosperous time periods.

Output				
log(GCESRS(t))	-5.906513808	Constant	1.25710648	log(GDPTRS(t-1))
Standard Error	1.683200081		0.10865941	
t-statistic	-3.51		11.57	

R^2	0.905
Adj. R^2	0.899
RMSE	0.067
AIC	-2.305

Regression time frame	
2000	Start year
2015	End year

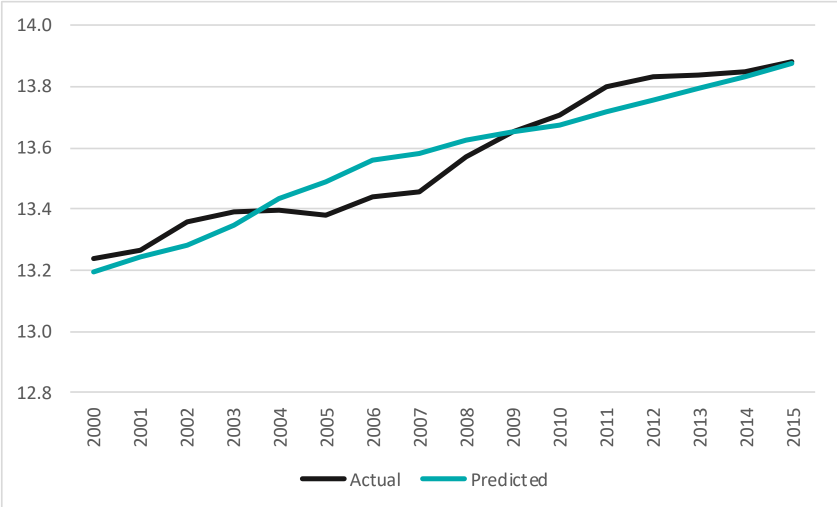

Figure 4: Estimation of Government Consumption

Source: Own figure

The regression output for estimating final energy consumption in transport (cetv[24]) is presented in Figure 5, where the estimation period begins in 2000. Alternatively, Figure 6 shows the same estimate starting in 1984. The two approaches are comparable in terms of quality measures. With regard to the GDPTRS regressor, the equation with the longer estimation period appears more plausible, because here the coefficient is smaller than 1 and thus the energy consumption does not develop overproportionately to the GDP. Moreover, since the stability of the model is not affected, the estimation with the longer estimation period is implemented.

Output						
log(cetv(t,24))	-9,987155335	Constant	1,20953285	log(GDPTRS(t))	0,491571182	D109FF(t)
Standard Error	1,960678022		0,12721428		0,044828296	
t-statistic	-5,09		9,51		10,97	

R^2	0,988
Adj. R^2	0,986
RMSE	0,049
AIC	-2,875

Regression time frame	
2000	Start year
2017	End year

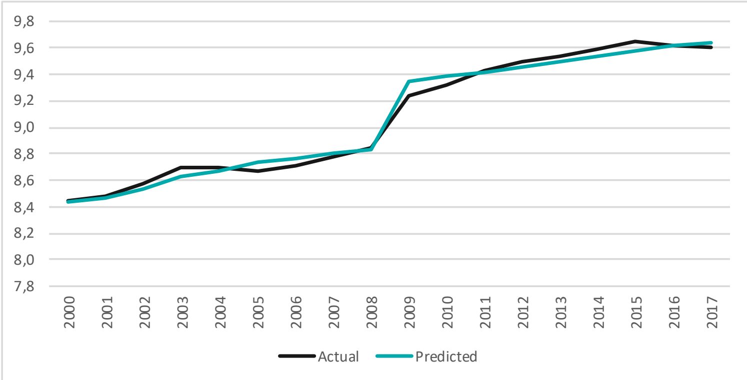

Figure 5: Estimation of energy consumption for transport with an estimation period from 2000 to 2017

Source: Own figure

Output						
log(cetv(t,24))	-5,08155577	Constant	0,89176508	log(GDPTRS(t))	0,576079674	D109FF(t)
Standard Error	1,029544827		0,06783199		0,044550546	
t-statistic	-4,94		13,15		12,93	

R^2	0,982
Adj. R^2	0,981
RMSE	0,065
AIC	-2,444

Regression time frame	
1984	Start year
2017	End year

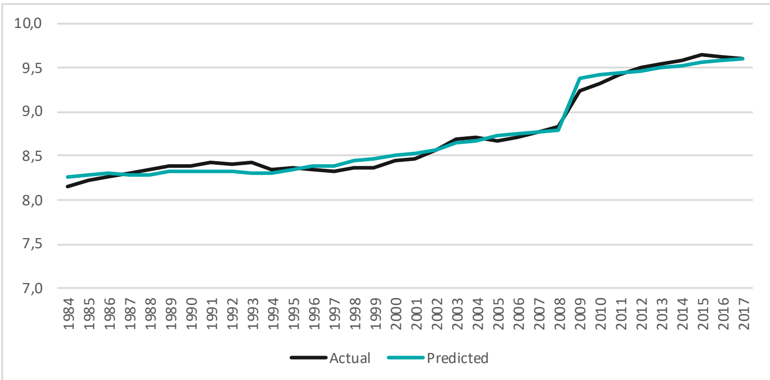

Figure 6: Estimation of energy consumption for transport with an estimation period from 1984 to 2017

Source: Own figure

Gross fixed capital formation (GFCFRS) is estimated on the basis of the GDP of previous periods. Figure 7 shows the approach which estimates gross fixed capital formation on the basis of the GDPs of the four previous years. In Figure 8, on the other hand, the regressor is only lagged by one year. The quality of the regression is almost unaffected.

One advantage of the first estimate is that the multi-annual delay will smooth future macroeconomic developments, which can be a stability advantage for the model over the long-term projection horizon up to 2050.

In the model, the estimation approach in Figure 7 is implemented. The elasticity to GDP growth, at 1.70, is slightly higher than under the alternative approach at 1.64, which increases long-term economic growth somewhat. This example shows that the choice of individual estimation equations also influences the long-term trend.

Output				
log(GFCFRS(t))	-12,17324131	Constant	1,70224612	log((4*GDPTRS(t-1)+3*GDPTRS(t-2)+2*GDPTRS(t-3)+1*GDPTRS(t-4))/10)
Standard Error	1,270692409		0,0830054	
t-statistic	-9,58		20,51	

R^2	0,993
Adj. R^2	0,992
RMSE	0,031
AIC	-3,806

Regression time frame	
2000	Start year
2017	End year

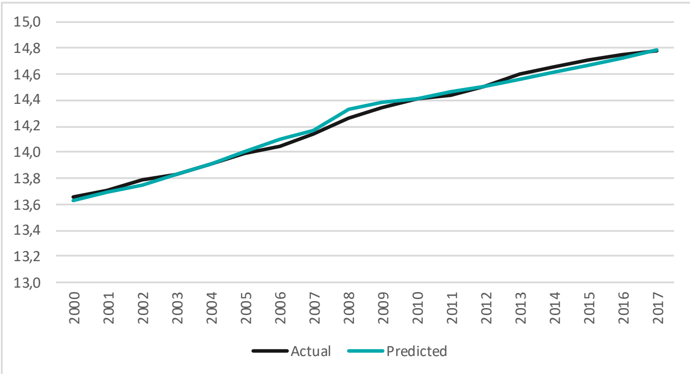

Figure 7: Estimation of gross fixed capital formation on the basis of a GDP with four lags

Source: Own figure

Output				
log(GFCFRS(t))	-11,31326081	Constant	1,64146906	log(GDPTRS(t-1))
Standard Error	1,387230397		0,09036465	
t-statistic	-8,16		18,16	

R^2	0,991
Adj. R^2	0,990
RMSE	0,034
AIC	-3,573

Regression time frame	
2000	Start year
2017	End year

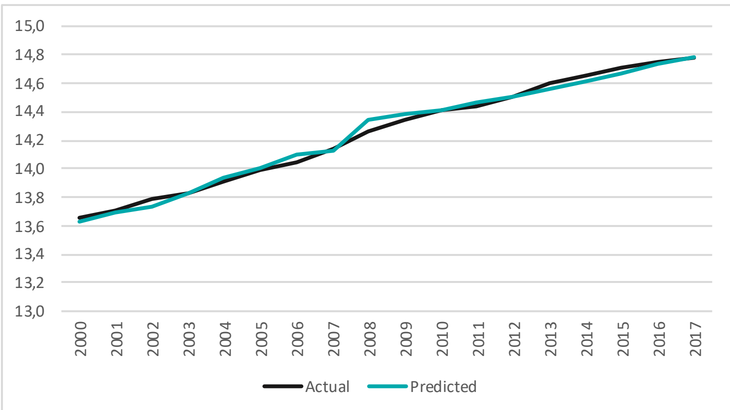

Figure 8: Estimation of gross fixed capital formation on the basis of a GDP with only one lag

Source: Own figure

1.4 SCENARIOS AND WHAT-IF ANALYSIS

The resulting simulation tool, i.e. the model e3.dz, can be used to simulate the effects of different pathways for the energy transition foreseen be the Algerian government. To do so, scenarios including the energy transition have to be compared to scenarios without any structural changes in the energy system. A scenario is a consistent set of assumptions about the future development of certain characteristic model quantities. For instance an energy transition scenario will be built from assumptions on renewable energy capacities installed, energy efficiency changes, prices of energy etc.

The results of this type of analysis, often called a "what-if" or "ceteris paribus analysis", hinge on the careful definition of the respective scenarios. The reference scenario should comprise a plausible and consistent projection of today's situation and past development. It is often denoted as a business-as-usual (BAU) development. To set up this scenario, assumptions on exogenous variables are needed, which will be identical across all scenarios. The policy scenarios then identify certain model variables, which change under the respective policy. Only variables characteristic for the policy can be altered, all other exogenous settings remain, hence the name ceteris paribus analysis. The economic simulation then gives results for economic indicators such as employment, GDP or production under the new circumstances of the scenario. The changes of these indicators can be interpreted as results of the respective policies, and answers the question "what happens to GDP, if we increase energy efficiency by x%?".

For all scenarios, the model requires exogenous information on population development, oil and gas prices, the exchange rate and the global trade volume.

1.5 CLASSIFICATION OF THE MODELLING APPROACH OF E3.DZ

In the literature, there are various classifications according to which models that combine the fields of economy, energy and climate can be classified. A paper by Nikas et al. (2019) divides the models into 6 classes, drawing on a detailed literature review:

- Optimal growth (or welfare optimization) IAMs represent the economy as a single all-encompassing sector. IAMs are designed to determine the climate policy and investment that maximize welfare (future against present consumption) over time, by identifying the emission abatement levels for each time step. They tend to be fairly simple, highly aggregated and transparent models that capture the trajectory of an economy and its interaction with climate in a fully integrated way.
- General equilibrium (or usually referred to as computable general equilibrium—CGE) models have a more detailed representation of the economy with multiple sectors and often include higher resolution of energy technologies and regional detail. Rather than seeking optimal policies, they consider the impacts of specific policies on economic, social and environmental parameters. The key disadvantage of CGE models can be considered to be the rational behavior of agents – which is not a realistic assumption in some cases.
- Partial equilibrium models provide a detailed analysis of the interaction between environmental impacts and a particular sector of the economy. These are usually used to assess potential climate-

induced damages to a specific sector of the economy and are often linked to computable general equilibrium models.

- Energy system models can be considered as a subcategory of partial equilibrium models that provide a detailed account of the energy sector, i.e. energy technologies and their associated costs. These are often used to determine the least-cost ways of attaining GHG emission reductions or the costs of alternative climate policies. They are often linked with computable general equilibrium or macroeconometric models in order to add the desired level of insight to top-down approaches.
- Macroeconometric models as e3.dz, like CGE models, can be quite detailed in terms of economic sectors and regional coverages and are also used to evaluate alternative climate policies. A major difference is that they do not assume that consumers and producers behave optimally or that markets clear and reach equilibrium in the short term. Instead, they use historical data and econometrically estimated parameters and relations to simulate the behavior of the economy dynamically and more realistically.
- Other integrated assessment models refer to models that may have little in common except that they do not fit neatly into any of the previous well-known groups. A key departure is that they model the economy in a highly "reduced form" or simply use exogenous growth scenarios (no model at all). Although they significantly differ from one another, they all tend to be more policy-oriented than models of the other five classes.

Important for the distinction are the terms top-down and bottom-up models. While top-down models explain economic development from a macroeconomic perspective and tend to take information about energy technologies from other model contexts, bottom-up models describe the energy system from a technological perspective. Economic variables are usually exogenous assumptions, while the energy system is cost optimized. For the calculation of green jobs, the description of change of economic structures or evaluation of monetary policy measures top-down models are used. Bottom-up models have advantages in describing detailed energy technology development. Both types of models are often used together to combine the strengths of both approaches.

2 DISCUSSION OF MODELLING EXPERIENCE AND OUTLOOK

The modelling approach applied in the model e3.dz is described in the literature as macroeconometric simulation model with input-output core, econometric IO models, or just macroeconometric models. The most widely applied models of this family have been developed by GWS and by Cambridge Econometrics. Cambridge Econometrics developed the global model e3me, e3-India, e3-US, e3-Thailand and e3-Brazil for India, the US, Thailand and Brazil and the UK regional model mdm-e3. The GWS family of models also hosts a global model (GINFORS_E), a model for Germany (INFORGE and its energy/environment extended version PANTA RHEI), a German regional model, and country models for Russia (e3.ru), Saudi Arabia (SaudiEcon), Austria (e3.at), now Algeria and upcoming for Georgia and Kazakhstan. To identify future questions for the application of e3.dz, it is helpful to give a quick overview of the analyses undertaken with its siblings, the questions answered and the policy decisions which followed.

2.1 INTERNATIONAL EXPERIENCES

2.1.1 REGIONAL COVERAGE

Cambridge Econometrics carried out an analysis of the economic effects of the energy efficiency policy at the EU level (Pollitt et al. 2017) using the model e3me. The analysis in the report estimates the positive and negative impacts of improvements in energy efficiency that could come about through a reduction of primary energy consumption, compared to a 2007 baseline projection, of 27%, 30%, 33%, 35% and 40% by 2030. Specific policy scenarios are defined to reach the respective target. The results are positive for both GDP and employment. With more ambitious energy efficiency targets, positive impacts on GDP and employment increase. Employment is found to be higher in sectors directly connected to energy efficiency activities (e.g. construction, engineering) but also in the wider economy.

An earlier report (Cambridge Econometrics 2015) applying the same model and running it in comparison with GEM-E3, the EU's CGE model, leads to the following observations. GDP impacts are positive in the macroeconometric model's results, while they are negative in the CGE results. This difference is mainly driven by a large increase in total investment in the macroeconometric model, while such an effect is not foreseen in the theoretical framework of a CGE model, thus reflecting the economic principles underlying the assumptions. In the CGE model, investment by households replaces current consumption, but industrial investment in energy efficiency crowds out other economic investments due to the restrictions on available finance. Hence, there is a much smaller increase in total investment and a smaller reduction in consumption. The results of the reports described and many other studies are part of the EU commissioned research on energy policy).

GWS' international model, **GINFORS_E**, has been employed for the analysis of international aspects of the "Energiewende" (Wünsch et al. 2015). GWS has focused on analyzing global value chains in renewable energy technologies and identified opportunities and challenges in international trade for the German industry. Results from different scenarios show how different developments will influence value added and production through deployment of renewable energy sources.

2.1.2 COUNTRY MODELS

CE's model **e3-India**, for instance, has been applied to model the Indian energy transition. The transition from coal power generation to solar and wind will according to the authors "not only ease the existing financial burden of non-performing assets in the power sector, it will also have positive spillover effects on other key sectors of the economy" (CE 2020, forthcoming).

GWS' model for Austria, **e3.at**, is a macroeconomic, multi-sector input-output model (Großmann et al. 2011) has been applied for various analyses for the Austrian government. It depicts the Austrian economy both as a whole and broken down by industrial sector. The model also takes into account regional developments at the federal state level. The model incorporates both supply and demand-side of the economy for all industrial sectors and goods categories. It represents the circular flow of income in full and differentiates between different economic sectors (e.g. corporations, the government, private households). The energy module comprises energy supply, energy conversion and energy demand from a range of consumers (e.g. the manufacturing sector, households) for various fossil and renewable energy sources. In Austria, domestic users and the transport sector are both significant energy consumers. To improve modelling of heating and vehicle fuel consumption, the model also incorporates characteristics of the housing stock and car inventories affecting energy consumption. The environment module depicts material consumption (biomass, minerals, fossil fuels) and CO_2 emissions.

Macroeconomic effects of the implementation of the EU targets for renewable energies and building efficiency in Austria by 2020 have been analyzed in 2008 (Großmann et al. 2008). Since Austria already uses a considerable part of its hydropower potential, this target can only be achieved in a meaningful way by a combination of reducing energy demand and expanding the use of renewable energy. If this strategy is pursued, positive macroeconomic effects will result, e.g. through increasing construction activity and the growing importance of exports of plants and components for the use of renewable energies. These positive effects are enhanced if similar efforts are made in other European member states.

e3.ru has been developed with support by the EU (Europe Aid/129527/C/SER/RU "Support to the development of new generation models to estimate and forecast GHG emissions and efficiency of Russian climate change mitigation measures and policy") and in cooperation with ICF and Plejades (Großmann et al. 2011). It covers the development of the Russian economy, environmental aspects (energy supply and demand, landuse model) and the development of greenhouse gas emissions until 2050. e3.ru has been used for analysing different scenarios and for producing greenhouse gas emission projections for Russian climate change adaptation strategies and policies. Capacity building was provided for the Russian Ministry of Economics.

The model **SaudiEcon** (Lutz et al. 2013) was used to support the Kingdom of Saudi Arabia to closely monitor household income development. The analysis studied an aggregate forecast of household income in Saudi Arabia for the period 2013–2035, estimated the number of future Saudi households by size and working members and applied the macroeconomic model for the Saudi economy based on national accounts data to obtain a projection of income as a function of GDP and based on sources of income.

PANTA RHEI is GWS' main model for the analysis of energy policy and climate change policy in Germany. PANTA RHEI is an extended version of the macroeconometric simulation and forecasting model INFORGE, designed for analyzing questions in the environmental economics field. The name, a quotation from the Greek philosopher Heraclites, means "everything flows" and sums up our approach perfectly. It models long-term structural change in economic development and in environmental-economic interdependencies. In addition to comprehensive economic modelling with our core INFORGE model, it also models energy consumption, air pollution, transport and land use and housing to a high level of detail.

Links between model components are consistent. The transport module, for example, models fuel consumption in liters, which, multiplied by the price per liter, feeds into input demand from the manufacturing sector and demand for consumer goods. Changes to fuel tax rates result in changes to tax receipts and a broad range of economic adaptation processes.

However, changes in fuel prices also lead to changes in behavior, which are also considered in our model. The model is resolved with full interdependence, meaning that the effects of a policy measure disseminate to all model variables simultaneously, and no effects are lost.

PANTA RHEI incorporates a multitude of macroeconomic variables drawn from various official statistics, in particular national and environmental-economic accounts (including input-output account) and provides sector-by-sector information on 63 industrial sectors. It also incorporates energy balances (including satellite balances for renewable energy) and German Federal Environment Agency emissions data.

The model has been used for a variety of purposes in recent years, including simulation of the net employment effects of renewable energy (Lehr et al. 2015) and provision of the basis for the progress report in the energy transition monitoring framework (Lutz et al. 2018).

Earlier, a list of environmental policies was simulated for the German Environmental Agency, comprising changes in energy prices, different export scenarios, different levels of consumption of goods, energy taxation, such as VAT on energy, value added tax on rail and air transport, CO2 tax (outside the ETS) and the abolition of ecotax. Other environment or energy related simulations include a resettlement levy and land tax reform or emissions trading, rehabilitation of buildings, other energy efficiency policies such as lower average fuel consumption for new car registrations, more energy efficiency in industry.

More recently, PANTA RHEI has been applied to estimate economic effects of increased global efforts in climate change mitigation, and increasingly economic effects from climate change adaptation. The latter results are part of the monitoring of the German Adaptation Strategy. Energy projections and impact assessment were part of the German contribution to the National Energy Climate Plans (NECP, https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en). Model simulations provide a comprehensive evaluation of its socio-economic and ecological consequences.

2.2 FURTHER APPLICATIONS OF E3.DZ

Key features of e3.dz lie in detailed modelling for each e3 component, which can be updated as soon as data are available, and in a modular extensible model architecture. It is transparent and allows for defining scenarios, and calculating own simulations and evaluating results.

The model can be expanded in many ways to give more detailed insights into the economic development. One option is detailing SNA accounts (government account: revenues and spending, especially accounting for revenues from oil/gas exports; private households including savings, disposable income; and the current account). This would allow for simulations regarding changes in subsidies, tax changes and other price related government policies. With more detailed data, the simplified modelling of GDP components might be expanded to use e.g. disposable income of households as an explaining variable of private consumption expenditures. Also import functions might be implemented on sector level, to better account for the different import shares of industries.

Inclusion of international funding (as part of climate finance) could offer an excellent opportunity to show positive socio-economic effects, and with regard to emissions, of internationally financed programs regarding either energy efficiency or new technologies. Developing these scenarios together with international stakeholders can help to attract the respective international funds to Algeria.

Given the interest of the Algerian government in diversification of the economy, the core IO table should be made time-dependent. Typically, for a dynamic input-output model the consumption structure and the largest coefficients in the technology matrix of the IO are estimated over time. New technologies might be modelled as a partly endogenous change in these structures based on expert knowledge. In more detailed models, demand for consumption purposes is estimated and then transferred via bridge matrices into consumption for goods.

The labor market could be differentiated in various ways. Employment data for all the sectors of the IO table would enable separate employment functions for these industries. Additionally, qualification levels could be introduced, to show what kind of qualifications (low, medium, high) are needed in different sectors and how they match the qualification of the labor force.

Further energy policy measures could also be included in the model, for example, efficiency measures in the transport sector, energy efficiency increases in the use of mineral oil or the conversion of vehicles to alternative drive trains.

Other new energy technologies are under discussion currently. Hydrogen strategies, storage options and power-to-gas or power-to-liquid technologies as synthetic fuels are discussed as future options in several (not only European) countries. Germany plans to adopt a hydrogen strategy until the end of the year 2019. It explicitly states the opportunities of cooperation with Africa. Inclusion of these technologies into the model could help to assess impacts of these policies on the Algerian economy.

Last but not least, the model might be extended by distributional data, which includes differing income levels and consumption structures, or by regional information.

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4 APPENDIX A: DATA

4.1 INPUT-OUTPUT TABLE

Code NSA	Intitulés des NSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total CI
1	Agriculture, sylviculture, pêche	80075	0	0	12811	1335	5917	90	4739	6062	718078	8	0	4655	128	174173	20555	2964	307	1031897
2	Eau et Energie	7539	40780	2970	2227	3336	30348	36885	5454	5373	6743	108	18	1005	181	41814	7344	3384	22580	218090
3	Hydrocarbures	5819	15867	904781	101816	476	1309	450	199889	1142	10679	17	0	38	11	164123	34	868	89	1407407
4	Services et Trav. Pub. Pétroliers	0	0	102609	145983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	248593
5	Mines et carrières	395	0	0	1430	8	14659	3947	56822	1809	237	1	0	9	3	0	0	9	0	79330
6	ISMMEE	45997	8807	6806	8748	2197	83225	1814	403502	2246	3599	63	1	245	132	94764	216	1757	265	664383
7	Matériaux de Construction	2433	348	995	75744	34	3485	2844	801558	632	148	0	0	25	5	1588	0	781	0	890620
8	BTPH	0	22000	2632	24156	3087	13056	2280	1847	2019	382	113	2	568	175	35046	1391	2142	220	111117
9	Chimie, Plastiques, Caoutchouc	87888	10863	1231	300	4415	22480	1871	197964	72180	356	548	28	864	2707	142849	118	2681	333	549677
10	Industries Agro-alimentaires	182690	0	55	18	0	4939	58	5226	15727	27297	44	64	37	7	66057	19791	1	39	322049
11	Textiles, confection, bonneterie	3890	2504	0	0	253	10420	545	2650	4053	117	26986	29	2060	33	34683	233	1281	867	90605
12	Cuirs et Chaussures	582	26322	0	0	1805	21089	2425	11	996	10	3292	3532	1876	2095	0	0	325	12675	77035
13	Bois, Papiers et lièges	11670	4647	9915	53177	2355	19830	5276	147498	7820	1093	232	6	9914	1086	63134	850	10560	119	349181
14	Industries diverses	4923	1386	0	0	300	3428	340	906	373	320	18	0	96	449	64082	99	8436	287	85443
15	Transports et communications	17520	7101	63509	32530	3531	31001	3051	4906	3921	2866	116	1	200	47	274944	2189	2690	340	450463
16	Hôtels café restaurants	0	8642	60	426	228	2079	233	2311	393	197	10	0	50	15	57557	184	2433	4	74822
17	Services fournis aux entreprises	1997	570	143862	4051	10	146	22	9342	78	24922	2	0	3	1	4257	29	289	1	189586
18	Services fournis aux ménages	18338	0	0	0	0	0	0	2495	0	1	0	0	0	2	53775	0	0	0	74611
Consommations Intermédiaires		471757	149837	1239426	463417	23370	267412	62133	1847118	124826	797045	31558	3682	21645	7076	1272846	53033	40601	38128	6914908

Figure 9: Quadrant A of the modified IOT in 2015

Sources: ONS 2019b and own manipulation.

Code NSA	Intitulés des NSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total CI
Valeurs Ajoutées (VA)		1936379	155632	3134252	57380	26070	124235	93186	1850769	71605	353721	15793	2789	20040	37799	3920103	212791	214536	202439	12429519
Rémunération des Salariés (RS)		205447	55376	141002	70126	9608	64422	33056	658323	27326	51915	7524	1051	10565	4889	495684	48270	67706	52171	2004459
Impôts liés à la production (ILP)		9912	6454	672651	4693	962	10609	5837	107836	3882	20631	1668	163	1943	630	148787	18426	8365	7074	1030521
Excédents Bruts d'Exploitation		1721020	93802	2320599	-17439	15501	49204	54294	1084610	40398	281175	6601	1576	7532	32280	3275633	146096	138464	143194	9394539
Consommation de Fonds Fixes		4613	90005	500494	86485	5247	51567	17400	125510	9019	27616	2069	186	1644	2661	393020	15386	22034	2884	1357839
Excédents Nets d'Exploitation		1716406	3797	1820105	-103924	10254	-2363	36894	959101	31379	253559	4532	1391	5888	29619	2882612	130710	116430	140310	8036700
Productions Brutes (PB)		2408136	305469	4373677	520797	49440	391647	155319	3697887	196431	1150765	47351	6471	41685	44875	5192950	265824	255137	240567	19344427
Importations biens et services		485488	0	238684	0	16868	2864011	105899	4992	713208	551684	110812	26131	195008	47339	132875	59719	551314	0	6104033
Taxes sur la Valeur Ajoutée		22294	21287	36291	0	3048	148117	14505	285	206508	98765	20235	5229	38386	7247	230405	19516	16227	24730	913073
Droits et taxes à l'importation		41016	0	56294	0	802	133816	7688	443	40482	64578	21727	6983	13981	7752	0	0	0	0	395561
Marges commerciales		251050	0	104823	0	7244	952399	231388	0	321143	634766	57517	2559	103415	15509	-2681815	0	0	0	0
Total des Ressources		3207984	326756	4809769	520797	77402	4489989	514799	3703607	1477773	2500558	257642	47373	392475	122721	2874414	345059	822678	265297	26757094

Figure 10: Quadrant B and C of the modified IOT in 2015

Sources: ONS 2019b and own manipulation

Code NSA	Intitulés des NSA	CF Ménages	CFAP	CFIF	CFAI	FBCF	Variation Stocks	Export B&S	Emplois finaux	Total des Emplois
1	Agriculture, sylviculture, pêche	1833011	138004	0	0	66895	125371	12806	2176087	3207984
2	Eau et Energie	104722	684	2945	315	0	0	0	108666	326756
3	Hydrocarbures	90427	12987	800	247	0	-41534	3339435	3402362	4809769
4	Services et Trav. Pub. Pétroliers	0	0	0	0	519468	-247264	0	272204	520797
5	Mines et carrières	0	1120	0	128	0	-12759	9582	-1929	77402
6	ISMMEE	269355	57357	7265	1711	2375422	1070401	44095	3825607	4489990
7	Matériaux de Construction	2445	5063	0	741	0	-386586	2515	-375821	514799
8	BTPH	75930	120900	0	1669	3674949	-280958	0	3592490	3703607
9	Chimie, Plastiques, Caoutchouc	303568	59690	322	828	37788	359965	165935	928096	1477772
10	Industries Agro-alimentaires	1112124	64524	15301	0	0	958957	27603	2178509	2500558
11	Textiles, confection, bonneterie	163501	6909	190	0	0	-5047	1485	167037	257642
12	Cuirs et Chaussures	48336	892	0	10	0	-80935	2036	-29662	47373
13	Bois, Papiers et lièges	58217	13673	3799	97	50104	-87463	4867	43294	392475
14	Industries diverses	65707	3454	687	106	12783	-46119	661	37278	122721
15	Transports et communications	2253382	54437	2424	205	0	0	113503	2423952	2874415
16	Hôtels café restaurants	187093	33604	3517	204	0	0	45820	270238	345059
17	Services fournis aux entreprises	0	25970	45239	479	421959	0	139445	633092	822678
18	Services fournis aux ménages	182482	7623	578	3	0	0	0	190686	265297
Consommations Intermédiaires		6750300	606891	83068	6743	7159367	1326029	3909789	19842186	26757094

Figure 11: Quadrant D of the modified IOT in 2015

Sources: ONS 2019b and own manipulation.

4.2 PRICES

For the user prices of mineral oil products, data from IEA database for Algeria were used (IEA 2019b). The reported units differ between fuel oil (industry), diesel, and gasoline, so data are uniformly converted into cDZD per liter (see Table 3).

Fuel oil is given in the unit DZD per ton and is converted with the density of heavy fuel oil.[1] Diesel is already presented in DZD per liter and is translated simply into cDZD per liter. For gasoline, there are two values (mid-grade and high-grade motor gasoline) from which the average is calculated.

1 ton of heavy fuel oil has the same energy content as 1046.471485 liters.

	Fuel oil (industry)		Diesel		Gasoline			
					midgrade motor gasoline	highgrade motor gasoline	average	
	DZD/ ton	cDZD/ liter	DZD/ liter	cDZD/ liter	DZD/ liter	DZD/ liter	DZD/ liter	cDZD/ liter
1990–1996	9479	906	10.6	1060	17.0	19.0	18.0	1800
1997	9896	946	11.3	1125	18.0	20.0	19.0	1900
1998	10281	982	11.5	1150	18.4	20.5	19.5	1945
1999–2001	10281	982	11.8	1175	19.2	21.3	20.2	2020
2002–2004	10281	982	11.8	1175	20.2	22.3	21.2	2120
2005–2015	10417	995	13.7	1370	21.2	23.0	22.1	2210
2016	15625	1493	18.8	1876	28.5	31.4	29.9	2994
2017	15625	1493	20.4	2042	32.7	35.7	34.2	3421
2018	15625	1493	23.1	2306	39.0	42.0	40.5	4046

Table 3: User prices for mineral oil products

Sources: IEA 2019b and own calculations.

4.3 ENERGY BALANCE

		Total Produits Solides	Total Produits Liquides	Total Produits Gazeux	Electricité	Total Général
1	PRODUCTION	10	65000	100702	150	165861
2	IMPORTATION	190	3873	0	126	4189
3	EXPORTATION	0	48597	59213	207	108017
4	SOUTAGES	0	240	0	0	240
5	VARI. STOCK (PROD.)	-16	269	69	0	322
6	DISPONIBILITES INTER.	216	18767	41420	69	61472
7	VARI. STOCK (CONSOM.)	-3	-51	28	0	-26
8	CONSOMMATION BRUTE	220	19818	41391	69	61498
9	TRANSFORMATION	-172	-2230	-16397	17743	-2056
10	CONSOM. NON ENERGE.	0	479	3007	0	3486
11	CONSOMMATION NETTE	47	16109	21987	17812	55956
12	CONSOM. INDUS. ENERG.	0	498	4575	1984	7057
13	CONSOMMATION FINALE	48	15338	15990	13270	44646
14	INDUSTRIE	45	710	4437	4750	9943
15	MATERIAUX DE CONSTRUCTION	0	9	3356	1005	4370
16	ISMME	38	0	258	469	765
17	SIDERURGIE DE BASE	38	0	258	103	399
18	CHIMIE	0	30	48	260	338
19	INDUSTRIES MANUFACTURIERES	0	0	588	546	1134
20	AGROALIMENTAIRE	0	0	553	458	1011
21	IND, TEXTILES, CUIR ET HABILLEMENT	0	0	35	88	123
22	BTP	0	356	4	81	441
23	AUTRES INDUSTRIES	7	315	184	2390	2895
24	TRANSPORTS	0	14095	548	252	14895
25	MENAGES ET AUTRES	3	533	11004	8268	19808
26	RESIDENTIEL	3	0	9874	5126	15003
27	AGRICULTURES	0	16	66	358	440
28	TERTIARE ET AUTRES	0	517	1063	2784	4364
29	PERTES	0	677	1159	2558	4394
30	ECART STATISTIQUE	-1	-404	264	0	-141

Figure 12: Reduced form of the energy balance 2017

Sources: MEM 2017.

5 APPENDIX B: MODEL DESCRIPTION

5.1 INTRODUCTION

Starting from the national modelling in the international GINFORS_E model, which is based on internationally accepted data, a similar modelling for Algeria is presented below on the basis of available national data. The key elements of the economic model are presented in the following figure. The national data provided by the Algerian partners were processed and linked according to the comprehensive description of the model.

The following figure provides an overview of the model. The model equation approaches are briefly described after the different parts of the model in the detailed description of the model equations.

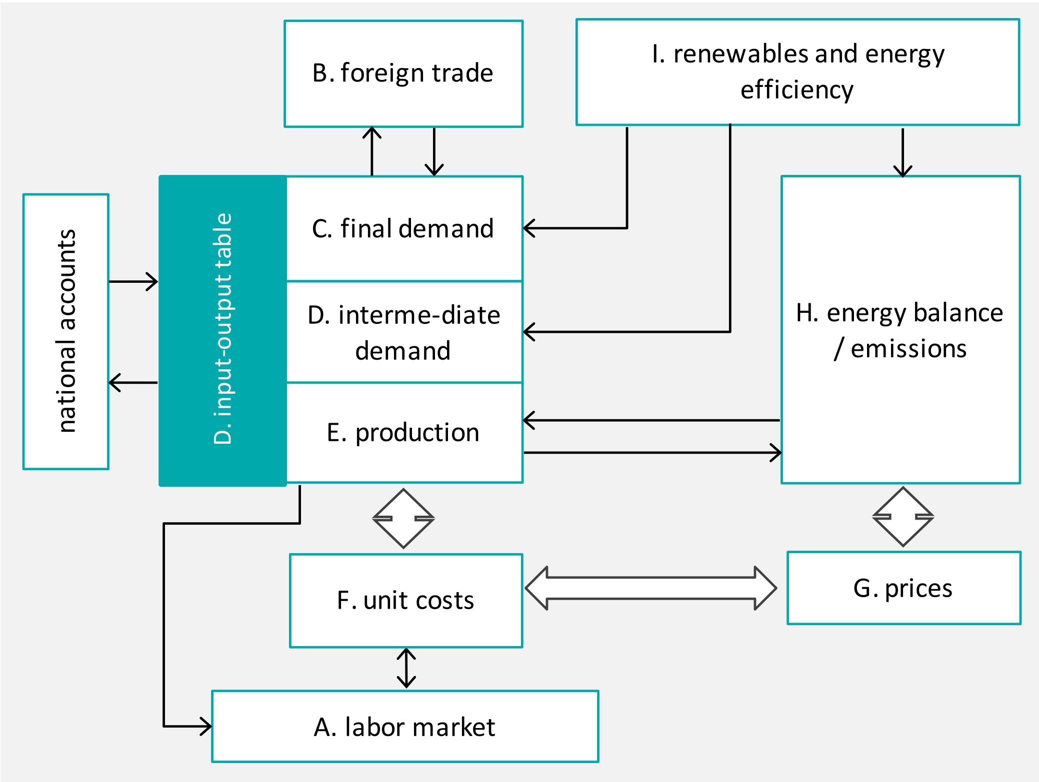

Figure 13: Overview of the model

Sources: Own figure.

The Excel model contains the equations according to the following description of the model and solves them until 2050. All results and correlations have been reviewed to see if they adequately reflect the developments in Algeria.

The exogenous variables were determined with the national experts for both the baseline development and the scenario development.

The variable names in the model consist of the names used in this document plus a suffix that specifies the variable type: An „S“ at the end indicates a scalar, a „v“ a vector and an „M“ a matrix. In addition, the names of scalars and matrices are written in uppercase letters and vectors in lowercase letters (see Table 4).

Variable	Scalar (S)	Vector (v)	Matrix (M)	Variable description	Description des variables
ADER			M	Additional installations / manufacturing of RE	Installations supplémentaires / fabrication supplémentaire d'énergie renouvelable
AN		v	M	Input coefficient matrix	Matrice de coefficient d'inputs
cet				Total of all energy sources in the energy balance	Total de toutes les sources d'énergie dans le bilan énergétique
CFAI	S			Consumption expenditures of real estate affairs	Consommation Finale Affaires Immobilières
CFIF	S			Consumption expenditures of financial institutions	Consumption expenditures of financial institutions
CIES	S			Changes in inventories	Variations de Stocks
cpe		v		Electricity in the energy balance	L'électricité dans le bilan énergétique
cpg		v		Total gas products in the energy balance	Total des produits gazeux dans le bilan énergétique
cpl		v		Total liquid products in the energy balance	Total des produits liquides dans le bilan énergétique
cpr		v		Renewables in the energy balance	Les énergies renouvelables dans le bilan énergétique
cps		v		Total solid products in the energy balance	Total des produits solides dans le bilan énergétique
D1xxFF				Dummy for years 20xx onwards	Dummy variable pour les années 20xx et suivantes
DDND	S			Domestic demand, current prices	Demande intérieure, prix courants
DDNDR	S			Domestic demand, constant prices	Demande intérieure, prix constants
ecd		v		Emissions of carbon dioxide	Émissions de dioxyde de carbone
EFEE			M	Direct employment from EE per DZD	Emploi direct d'efficacité énergétique par DZD
EFER			M	Direct employment from RE per MW	Emploi direct des énergies renouvelables par MW
EGSS	S			Exports of goods & services, current prices	Exportations de Biens et Services, prix courants
EGSSHE	S			Export of goods and services without oil and gas, current prices	Exportations de biens et services hors pétrole et gaz, prix courants
EGSSHEP	S			Export price index of goods and services without oil and gas	Exportations de biens et services hors pétrole et gaz, indice de prix
EGSSHER	S			Export of goods and services without oil and gas, constant prices	Exportations de biens et services hors pétrole et gaz, prix constants
EGSSOG	S			Exports of goods and services of oil and gas, current prices	Exportations de biens et services de pétrole et gaz, prix courants

Variable	Scalar (S)	Vector (v)	Matrix (M)	Variable description	Description des variables
EGSSOGP	S			Export price index of oil and gas	Exportations de biens et services de pétrole et gaz, indice de prix
EGSSOGR	S			Exports of goods and services of oil and gas, constant prices	Exportations de biens et services de pétrole et gaz, prix constants
EGSSP	S			Export price index of goods and services	Exportations de Biens et Services, indice de prix
EGSSR	S			Exports of goods and services, constant prices	Exportations de Biens et Services, prix constants
EMEE			M	Direct employment from EE	Emploi direct d'efficacité énergétique
EMER			M	Direct employment from RE	Emploi direct des énergies renouve-lables
EMPL	S			Employment	Emploi
EMPLA	S			Employment in agriculture	Emploi dans l'agriculture
EMPLB	S			Employment in the construction sector	Emploi dans le secteur de la bâtiment
EMPLI	S			Employment in industry	Emploi dans l'industrie
EMPLS	S			Employment in the service sector	Emploi dans le secteur des services
epel		v		User price for electricity	Prix de vente de l'électricité
epgz		v		User price for gas	Prix de vente du gaz naturel
EXRA	S			Exchange rate DZD in USD	Taux de change
fcd		v		Emission factor of carbon dioxide	Coefficient d'émission du dioxyde de carbone
GCES	S			Government consumption expen-ditures, current prices	Consommation finale des administra-tions publiques, prix courants
GCESP	S			Government consumption expen-ditures, price index	Consommation finale des administra-tions publiques, indice de prix
GCESR	S			Government consumption expen-ditures, constant prices	Consommation finale des administra-tions publiques, prix constants
GDPHE	S			GDP without oil and gas, current prices	PIB hors pétrole et gaz, prix courants
GDPHEP	S			GDP without oil and gas, price index	PIB hors pétrole et gaz, indice de prix
GDPHER	S			GDP without oil and gas, constant prices	PIB hors pétrole et gaz, prix constants
GDPOG	S			Oil and gas related GDP, current prices	PIB lié au pétrole et au gaz, prix courants
GDPOGP	S			Oil and gas related GDP, price index	PIB lié au pétrole et au gaz, indice de prix
GDPOGR	S			Oil and gas related GDP, constant prices	PIB lié au pétrole et au gaz, prix constants
GDPT	S			Gross domestic product, current prices	Produit Intérieur Brut, prix courants
GDPTP	S			GDP, price index	PIB, indice de prix

Variable	Scalar (S)	Vector (v)	Matrix (M)	Variable description	Description des variables
GDPTR	S			Gross domestic product, constant prices	Produit Intérieur Brut, prix constants
GFCF	S			Gross Fixed Capital Formation, current prices	Formation brute du capital fixe, prix courants
GFCFP	S			Gross fixed capital formation, price index	Formation brute du capital fixe, indice de prix
GFCFR	S			Gross fixed capital formation, constant prices	Formation brute du capital fixe, prix constants
GFER	S			(Additional) investment in renewable energy in current prices	Investissements (supplémentaires) dans les énergies renouvelables en prix courants
GFERR	S			(Additional) investment in renewable energy in constant prices	Investissements (supplémentaires) dans les énergies renouvelables en prix constants
gfee		v		(Additional) investment in EE	Investissements (supplémentaires) dans EE
gfer		v		(Additional) investment in RE	Investissements (supplémentaires) dans ER
HCES	S			Household consumption expenditures, current prices	Consommation finale individuelle des ménages, prix courants
HCESP	S			Household consumption expenditures, price index	Consommation finale individuelle des ménages, indice de prix
HCESR	S			Household consumption expenditures, constant prices	Consommation finale individuelle des ménages, prix constants
hpc		v		Full load hours	Heures de pleine charge
IGSS	S	v		Imports of Goods & Services, current prices	Importations de Biens et Services, prix courants
IGSSP	S	v		Imports of goods and services, price index	Importations de Biens et Services, indice de prix
IGSSR	S	v		Imports of goods and services, constant prices	Importations de Biens et Services, prix constants
inser		v		RE capacity installed	Capacité d'énergie renouvelable installée
io_cfai		v		Consumption expenditures of real estate affairs	Consommation Finale Affaires Immobilières
io_cfais		v		Constant share of io_cfai	Proportion constante d'io_cfai
io_cff		v		Depreciation	Consommation de fonds fixes
io_cffs		v		Constant share of io_cff	Proportion constante d'io_cff
io_cfif		v		Consumption expenditures of financial institutions	Consommation des institutions financières
io_cfifs		v		Constant share of io_cfif	Proportion constante d'io_cfif
io_ci		v		Intermediate consumption	Consommations intermédiaires
io_cies		v		Changes in inventories	Variations de stocks
io_ciess		v		Constant share of io_cies	Proportion constante d'io_cies

Variable	Scalar (S)	Vector (v)	Matrix (M)	Variable description	Description des variables
io_dti		v		Taxes and duties on imports	Droits et taxes à l'importations
io_dtis		v		Constant share of io_dti	Proportion constante d'io_dti
io_ebe		v		Gross operating surplus	Excédents bruts d'exploitation
io_egss		v		Exports of goods & services	Exportations de Biens et Services
io_egsss		v		Constant share of io_egss	Proportion constante d' io_egss
io_ene		v		Net operating surplus	Excédents nets d'exploitation
io_enes		v		Constant share of io_ene	Proportion constante d' io_ene
io_fd		v		Final demand	Demande finale
io_gces		v		Government consumption expenditures	Consommation finale des administrations publiques
io_gcess		v		Constant share of io_gces	Proportion constante d'io_gces
io_gfcf		v		Gross fixed capital formation	Formation brute du capital fixe
io_gfcfs		v		Constant share of io_gfcf	Proportion constante d'io_gfcf
io_hces		v		Household consumption expenditures	Consommation finale individuelles des ménages
io_hcess		v		Constant share of io_hces	Proportion constante d'io_hces
io_id		v		Intermediate demand	Demande intermédiaires
io_ilp		v		Taxes on production	Impôts liés à la production
io_ilps		v		Constant share of io_ilp	Proportion constante d'io_ilp
io_im		v		Imports	Importations
io_ims		v		Constant share of io_im	Proportion constante d' io_im
io_mc		v		Commercial margin	Marges commerciales
io_mcs		v		Constant share of io_mc	Proportion constante d'io_mc
io_pb		v		Gross production in current prices	Production brute, prix courants
io_rs		v		Salaries	Rémunération des salariés
io_rss		v		Constant share of io_rs	Proportion constante d'io_rs
io_td		v		Total demand	Demande totale
io_tr		v		Total supply	Total des ressources
io_tva		v		Value added tax	Taxes sur la valeur ajoutée
io_tvas		v		Constant share of io_tva	Proportion constante d'io_tva
io_va		v		Value added	Valeurs ajoutées
IPEEI			M	Input structure for EE measures – installation	Structure d'entrée pour les mesures d'EE – installation
IPEEM			M	Input structure for EE measures – manufacturing	Structure d'entrée pour les mesures d'EE – fabrication
IPERI			M	Input structure for RE – installation	Structure d'entrée pour ER – installation
IPERM			M	Input structure for RE – manufacturing	Structure d'entrée pour ER – fabrication
IPERO			M	Input structure for RE – operations & maintenance	Structure d'entrée pour ER – exploitation et maintenance

Variable	Scalar (S)	Vector (v)	Matrix (M)	Variable description	Description des variables
LFCE	S			Labor Force	Force de travail
LIMM			M	Leontief Inverse	Inverse de Leontief
opmac		v		Share for annual spending on operation and maintenance	Part des dépenses annuelles d'exploitation et de maintenance
pbp		v		Gross production price indexes	Production brute, indices de prix
pbr		v		Gross production in constant prices	Production brute, prix constants
POPA	S			Working age population	Population active
POPU	S			Population	Population au milieu de l'année
PRER			M	Prices for RE	Prix pour les énergies renouvelables
rdeff		v		Reduction in energy demand by efficiency	Réduction de la demande d'énergie par l'efficacité énergétique
SPGEE			M	Spending on EE	Dépenses pour EE
SPGER			M	Spending on RE	Dépenses pour ER
TIME	S			Time variable	Variable dans le temps
TIMEL	S			Time variable, logarithmised (log(TIME - 1960))	Variable dans le temps, logarithmique (log(TIME - 1960))
TIMES	S			Time variable, S-shaped	Variable dans le temps, en forme de S
uc		v		Unit costs	Coûts unitaires
UNEM	S			Unemployment	Chômage
WAGE	S			Wages, salaries	Rémunération des salariés
WAGEC	S			Wages per capita (WAGE/EMPL)	Rémunération des salariés par tête (WAGE/EMPL)
WPCOAL	S			World market price for coal in USD	Prix du charbon sur le marché mondial en USD
WPCOALDZ	S			World market price for coal	Prix du charbon sur le marché mondial
WPGAS	S			World market price for natural gas in USD	Prix du gaz naturel sur le marché mondial en USD
WPGASDZ	S			World market price for natural gas	Prix du gaz naturel sur le marché mondial
WPOIL	S			World market price for crude oil in USD	Prix du pétrole brut sur le marché mondial en USD
WPOILDZ	S			World market price for crude oil	Prix du pétrole brut sur le marché mondial
WWTRADE	S			World trade volume	Commerce mondial
YN			M	IOT input matrix	Cadrent A

Table 4: The model variables

Source: Own table.

5.2 LABOUR MARKET (A)

Population et population active / Population and working age population[2]

1) *POPU, exogenous*

2) *POPA, exogenous*

3) *TIME, exogenous*

according to the national projection

Force de travail / Labour Force

4) *LFCE, exogenous*

Rémunération des salariés par tête / Wages per capita

5) *WAGEC = f (GDPTR[t-1]/EMPL[t-1]*HCESP[t-1], LFCE[t-1]/EMPL[t-1])*

Rémunération des salariés / Wages

6) *WAGE = WAGEC * EMPL*

Emploi / Employment

for agriculture A, industry I, building B and services S:

7) $EMPLA = EMPLAS[t-1] * pbr_1[t]/pbr_1[t-1] / 1.02$

8) $EMPLB = f(pbr_8[t], WAGE[t-1]/pbp_8[t]) + \sum_{k=1}^{6} EMER_{k,2}$ (l=installations)

9) $EMPLI = f(pbr_2+pbr_3+pbr_4+pbr_5+pbr_6+pbr_7+pbr_9+pbr_{10}+pbr_{11}+pbr_{12}+pbr_{13}+pbr_{14}) + \sum_{k=1}^{6} EMER_{k,1}$ (l=manufacturing)

10) $EMPLS = f(pbr_{15}[t]+pbr_{16}[t]+pbr_{17}[t]+pbr_{18}[t], WAGE[t-1]/pbp_{15}[t]) + \sum_{k=1}^{6} EMER_{k,3}$ (l=O&M)

11) *EMPL = EMPLA + EMPLB + EMPLI+ EMPLS*

Chômage / Unemployment

12) *UNEM = LFCE – EMPL*

5.3 FOREIGN TRADE (B)

Commerce mondial / World trade volume

13) *WWTRADE, exogène*

Taux de change / Exchange rate

14) *EXRA, exogène*

2 All descriptions are in French and English to facilitate the use in Algeria.

Importations de biens et services en prix courants / Imports of goods and services in current prices

15) *IGSS = IGSSR * IGSSP / 100*

Importations de biens et services en prix constants / Imports of goods and services in constant prices

16) *IGSSR = f (DDNDR) (see below)*

Indice des prix à l'importation des biens et services / Import price index of goods and services

17) *IGSSP = exogène*

Exportations des biens et services hors pétrole/gaz en prix constants / Exports of goods and services without oil and gaz in constant prices

18) *EGSSHER[t] = EGSSHER[t-1] * WWTRADE[t] / WWTRADE[t-1]*

The estimation method does not yield significant results. Exports are therefore extrapolated to the growth rate of the world trade volume.

Exportations de biens et services hors pétrole/gaz en prix courants / Exports of goods and services without oil and gas in current prices

19) *EGSSHE = EGSSHER * EGSSHEP / 100*

Indice des prix à l'exportation des biens et services hors pétrolel/gaz en prix / Export price index of goods and services without oil and gas

20) *EGSSHEP = f (GDPTP)*

Exportations des biens et services de pétrole/gaz en prix constants / Exports of goods and services of oil and gaz in constant prices

21) $EGSSOGR[t] = EGSSOGR[t-1] * (cpl_3[t] + cpg_3[t]) / (cpl_3[t-1] + cpg_3[t-1])$

Exportations de pétrole/gaz en prix courants / Exports of oil and gas in current prices

22) *EGSSOG = EGSSOGR * EGSSOGP / 100*

Indice des prix à l'exportation de pétrole et gaz / Export price index of oil and gas

23) *EGSSOGP = f (WPOILDZ, WPGASDZ)*

Exportations de biens et services en prix courants / Exports of goods and services in current prices

24) *EGSS = EGSSHE + EGSSOG*

Exportations des biens et services en prix constants / Exports of goods and services in constant prices

25) *EGSSR = EGSSHER + EGSSOGR*

Indice des prix à l'exportation des biens et services / Export price index of goods and services

26) *EGSSP = EGSS / EGSSR * 100*

5.4 FINAL DEMAND (C)

Consommation finale individuelle des ménages en prix courants / Household consumption expenditures in current prices

27) *HCES = HCESR * HCESP / 100*

Consommation finale individuelle des ménages en prix constants / Household consumption expenditures in constant prices

28) *HCESR = f (GDPHER[t-1])*

Consommation finale individuelle des ménages, indice des prix / Household consumption expenditures, price index

29) *HCESP = f (WAGEC, IGSSP)*

Consommation finale des administrations publiques en prix courants / Government consumption expenditures in current prices

30) *GCES = GCESR * GCESP / 100.0*

Consommation finale des administrations publiques en prix constants / Government consumption expenditures in constant prices

31) *GCESR = f (GDPTRS[t-1])*

Consommation finale des administrations publiques, indice des prix / Government consumption expenditures, price index

32) *GCESP = f (WAGEC[t-1], IGSSP)*

Consommation Finale des Institutions Financières en prix courants / Consumption expenditures of financial institutions in current prices

33) *CFIF = f (GDPT[t-1], TIMES)*

Consommation Finale Affaires Immobilières en prix courants / Consumption expenditures of real estate affairs in current prices

34) *CFAI = f (GDPT[t-1])*

Formation brute du capital fixe en prix courants / Gross fixed capital formation in current prices

35) *GFCF = GFCFR * GFCFP / 100*

Formation brute du capital fixe en prix constants / Gross fixed capital formation in constant prices

36) *GFCFR = f ((4*GDPTR[t-1] + 3*GDPTR[t-2] + 2*GDPTR[t-3] + 1*GDPTR[t-4])/10)*

Investissements (supplémentaires) dans les énergies renouvelables en prix courrants / (Additional) investment in renewable energy in current prices

37) $GFER = \sum_{scr=1}^{18} gfer_{scr}$

Investissements (supplémentaires) dans les énergies renouvelables en prix constants / (Additional) investment in renewable energy in constant prices

38) $GFERR = GFER / GFCFP * 100$

Investissements (supplémentaires) dans l'efficacité énergétique en prix courants / (Additional) investment in energy efficiency in current prices

39) $GFEE = \sum_{scr=1}^{18} gfee_{scr}$

Investissements (supplémentaires) dans l'efficacité énergétique en prix constants / (Additional) investment in energy efficiency in constant prices

40) $GFEER = GFEE / GFCFP * 100$

Formation brute du capital fixe, indice des prix / Gross fixed capital formation, price index

41) $GFCFP = f\ (WAGEC[t-1], IGSSP)$

Variations des stocks / Changes in inventories

42) $CIES = constant$

Demande intérieure en prix courants / Domestic demand in current prices

43) $DDND = HCES + GCES + GFCF + GFER + GFEE + CIES$

Demande intérieure en prix constants / Domestic demand in constant prices

44) $DDNDR = HCESR + GCESR + GFCFR + GFERR + GFEER + CIES / GDPTP * 100$

PIB en prix courants / GDP in current prices

45) $GDPT = DDND + EGSS – IGSS$

PIB en prix constants / GDP in constant prices

46) $GDPTR = GDPTR[t-1] * (DDNDR + EGSSR - IGSSR) / (DDNDR[t-1] + EGSSR[t-1] - IGSSR[t-1])$

PIB, indice de prix / GDP, price index

47) $GDPTP = GDPT / GDPTR * 100$

PIB lié au pétrole et gaz en prix courants / Oil and gas related GDP in current prices

48) $GDPOG = va_3 / \sum va * GDPT$

PIB lié au pétrole et gaz, indice de prix / Oil and gas related GDP, price index

49) $GDPOGP = pbp_3$

PIB lié au pétrole et gaz en prix constants / Oil and gas related GDP in constant prices

50) *GDPOGR = GDPOG / GDPOGP * 100*

PIB hors pétrole et gaz en prix courants / GDP without oil and gas in current prices

51) *GDPHE = GDPT – GDPOG*

PIB hors pétrole et gaz en prix courants / GDP without oil and gas in constant prices

52) *GDPHER = GDPTR – GDPOGR*

PIB hors pétrole et gaz, indice de prix / GDP without oil and gas, price index

53) *GDPHEP = GDPHE / GDPHER * 100*

5.5 INPUT-OUTPUT TABLE (D)

5.5.1 QUADRANT A

Coefficient d'inputs / Input coefficients

54) *$AN_{i,j} = YN_{i,j}$ [2015]/ io_pb_j [2015]*100 (pour i = 1,...,18, j = 1,...18) (is not calculated in the model, but given in the sheet „Values")*

i = rows, j = columns of the input-output table

AN = constant

Inputs intermédiaires / Intermediate inputs

55) $YN_{i,j} = AN_{i,j} * io\_pb_j/100$ *(pour i = 1,...,18, j = 1,...18)*

Consommations intermédiaires / Intermediate consumption

56) $io\_ci = \sum_{i=1}^{18} YNij$

Demande intermédiaire / Intermediate demand

57) $io\_id = \sum_{j=1}^{18} YNij$

			Sector 1	Sector 2	...	Sector 18	Intermediate demand
							io_id
1	Agriculture, forestry, fishing	$AN_{i,j} = YN_{i,j}/pb_j$	$YN_{1,1}$	$YN_{1,2}$	...	$YN_{1,18}$	$= YN_{1,1} + ... + YN_{1,18}$
2	Water and energy		$YN_{2,1}$	...	...	...	$= YN_{2,1} + ... + YN_{2,18}$
...	...		...	...	...	...	...
18	Services provided to households		$YN_{18,1}$	...	...	$YN_{18,18}$	Intermediate input factors from sector 18 to all other sectors
	Intemediate consumption	io_ci	$= YN_{1,1} + ... + YN_{18,1}$	Intermediate input factors of sector 2 from all other sectors			

Figure 14: Overview of quadrant A in the IOT

Source: GWS on the basis of ONS (2019).

5.5.2 QUADRANTS B AND C

		Sector 1	Sector 2	...	Sector 18
Value added	io_va	= io_pb - io_ci	...	...	...
Salaries	io_rs	cs of io_va	...	...	
Taxes on production	io_ilp	cs of io_pb	...	...	...
Gross operating surplus	io_ebe	= io_va - io_rs - io_ilp	...	...	...
Depreciation	io_cff	cs of io_ebe	...	...	...
Net operating surplus	io_ene	= io_ebe - io_cff	...	...	...
Gross production	io_pb	= (I-AN)^(-1) * (io_fd - io_im - io_tva - io_dti - io_mc) via Leontief-Inverse	...	...	...
Imports	io_im	cs of IGSS	...	...	...
Taxes (VAT)	io_tva	value in 2015 plus constant tax rate on additional value added	...	...	...
Taxes and duties on imports	io_dti	cs of io_im	...	...	...
Commercial margin	io_mc	cs of io_pb	...	...	...
Total	io_tr	= io_pb + io_im + io_tva + io_dti + io_mc	...	...	...
cs = constant share					

Figure 15: Overview of quadrants B and C in the IOT

Source: GWS on the basis of ONS (2019).

In vector notation:

Productions brutes / Gross production

58) $io\_pb = (I - AN)^{-1} * (io\_fd - io\_im - io\_tva - io\_dti - io\_mc)$

io_pb = vector of gross production

io_fd = vector of final demand

io_im = vector of imports

io_tva = vector of value added tax

io_dti = vector of import duties and taxes

io_mc = vector of commercial margins

AN = input coefficient matrix (constant)

I = identity matrix

LIMM = $(I - AN)^{-1}$ = Leontief inverse

Valeurs ajoutées / Value added

59) $io\_va = io\_pb - io\_ci$

Rémunération des salariés / Salaries

60) $io\_rss = io\_rs[2015] / io\_va[2015]$ *(constant)*

61) $io\_rs = io\_rss * io\_va$

Impôts liés à la production / Taxes on production

62) *io_ilps = io_ilp[2015]/ io_pb[2015] (constant)*

63) *io_ilp = io_ilps * io_pb*

Excédents bruts d'exploitation / Gross operating surplus

64) *io_ebe = io_va - io_rs - io_ilp*

Consommation de fonds fixes / Depreciation

65) *io_cffs = io_cff[2015]/ io_ebe[2015] (constant)*

66) *io_cff = io_cffs * io_ebe*

Excédents nets d'exploitation / Net operating surplus

67) *io_ene = io_ebe – io_cff*

Importations / Imports

68) *io_ims = io_im[2015]/IGSS[2015] (constant)*

69) *io_im = io_ims * IGSS*

Taxes sur la valeur ajoutée / Value added tax

70) *io_tvas = exogenous (at the moment: average io_tva of 2015)*

71) *io_tva = io_tva[2015] + io_tvas * (io_va – io_va[2015])*

Droits et taxes à l'importations / Taxes and duties on imports

72) *io_dtis = io_dti[2015]/ io_im[2015] (constant)*

73) *io_dti = io_dtis * io_im*

Marges commerciales / Commercial margin

74) $io\_mcs_{15} = io\_mc_{15}[2015]/ io\_pb_{15}[2015]$ *(constant) (Transport and communications)*

75) $io\_mcsj = io\_mc_j[2015]/ io\_mc_{15}[2015]$ *(constant) for j = 1,...,14 (constant share for 2015)*

Commercial margins are reduced by 1% per year in order to stabilize the model.

76) $io\_mc_{15} = io\_mcs_{15} * io\_pb_{15} * (1 - 0.01 * (t - 2015))$

77) $io\_mc_j = io\_mcs_j * io\_mc15$ *pour j = 1,...,14*

Total des ressources / Total supply (resources)

78) *io_tr = io_pb + io_im + io_tva + io_dti + io_mc*

5.5.3 QUADRANT D

		House-hold consump-tion expendi-tures	Govern-ment consump-tion expendi-tures	Consump-tion expendi-tures of financial institutions	Consump-tion expendi-tures of real estate affairs	Gross fixed capital formation	Changes in inventories	Exports of goods and services	Final demand	Total demand
		io_hces	io_gces	io_cfif	io_cfai	io_gfcf	io_cies	io_egss	io_fd	io_td
1	Agriculture, forestry, fishing	cs of HCES	cs of GCES	cs of CFIF	cs of CFAI	cs of GFCF	cs of CIES	cs of EGSSOG	= d'io_hces + io_gces + io_cfif + io_cfai + io_gfcf + io_cies + io_egss	= io_id + io_fd
2	Water and energy	cs of HCES	cs of GCES	cs of CFIF	cs of CFAI	cs of GFCF	cs of CIES	cs of EGSSOG	= d'io_hces + io_gces + io_cfif + io_cfai + io_gfcf + io_cies + io_egss	= io_id + io_fd
...	...	...	...	...	...	...	...	...	...	...
18	Services provided to households	cs of HCES	cs of GCES	cs of CFIF	cs of CFAI	cs of GFCF	cs of CIES	cs of EGSSOG	= d'io_hces + io_gces + io_cfif + io_cfai + io_gfcf + io_cies + io_egss	= io_id + io_fd
cs = constant share										

Figure 16: Overview of quadrant D in the IOT

Source: GWS on the basis of ONS (2019).

Consommation Finale Individuelle des Ménages / Household consumption expenditures

79) $io\_hcesv\_sum[t] = \sum_{i=1}^{18} HCES[t]/HCES[2015]*\ io\_hces_i\ \ [t]$

80) $io\_hcess_i = io\_hces_i[2015]/\ (io\_hcesv\_sum[2015] - io\_hces_2[2015] - io\_hces_3[2015])$ *(constant)*

81) *pour* $i=1, 4, 5,...,18$: $io\_hces_i = io\_hcess_i * (io\_hcesv\_sum[t] - io\_hces_2[t] - io\_hces_3[t])$

82) *pour* $i=2$: $io\_hces_2[t] = io\_hces_2[t-1] * (epel_3[t] * cpe_{26}[t]) / (epel_3[t-1] * cpe_{26}[t-1])$

83) *pour* $i=3$: $io\_hces_3[t] = io\_hces_3[t-1] * (epgz_3[t] * cpg_{26}[t]) / (epgz_3[t-1] * cpg_{26}[t-1])$

Consommation Finale des Administrations Publiques / Government consumption expenditures

84) $io\_gcess = io\_gces[2015]/GCES[2015]$ *(constant)*

85) $io\_gces = io\_gcess * GCES$

Consommation Finale des Institutions Financières / Consumption expenditures of financial institutions

86) $io\_cfifs = io\_cfif[2015]/CFIF[2015]$ *(constant)*

87) $io\_cfif = io\_cfifs * CFIF$

Consommation Finale Affaires Immobilières / Consumption expenditures of real estate affairs

88) $io\_cfais = io\_cfai[2015]/CFAI[2015]$ *(constant)*

89) $io\_cfai = io\_cfais * CFAI$

Formation Brute du capital fixe / Gross fixed capital formation

90) $io\_gfcfs = io\_gfcf[2015]/GFCF[2015]$ *(constant)*

91) $io\_gfcf = io\_gfcfs * GFCF$

Variation de stocks / Changes in inventories

92) $io\_ciess = io\_cies[2015]/CIES[2015]$ *(constant)*

93) $io\_cies = io\_ciess * CIES$

Exportations hors pétrole et gaz/ Exports without oil and gas

94) $io\_egsss_i = io\_egss_i[2015]/EGSSHE[2015]$ *(constant), for* $i \neq 3$

95) $io\_egss_i = io\_egsss_i * EGSSHE$, *for* $i \neq 3$

Exportations de pétrole et gaz/ Exports of oil and gas

96) $io\_egsss_3 = io\_egss_3[2015]/EGSSOG[2015]$ *(constant)*

97) $io\_egss_3 = io\_egsss_3 * EGSSOG$

Demande finale / Final demand

98) $io\_fd = io\_hces + io\_gces + io\_cfif + io\_cfai + io\_gfcf + io\_cies + io\_egss$

Demande totale / Total demand

99) $io\_td = io\_id + io\_fd$

5.6 UNIT COSTS AND PRICES (F, G)

Coûts unitaires / Unit costs

100) $uc_j = \sum_{i=1}^{18} (AN_{ij} * pbp_i) + WAGEC/WAGEC(2000) * io\_rs_j / io\_pb_j * 100$

The cost components (IOT column) of the corresponding sector j are multiplied by the row prices i (AN) or the wage index per capita (for io_rs), respectively.

Indices de prix á la production brute / Gross production price indices (2000 = 100)

101) $pbp_j[t] = pbp_j[t-1] * (0{,}5 * uc_j[t] / uc_j[t-1] + 0{,}5 * IGSSP[t] / IGSSP[t-1])$ *for j = 1; 4,...,18 (assumption: sectoral price developments are determined equally by domestic unit costs and import prices be cause the effects of import prices cannot be estimated due to missing structural data)*

for j = 3:

102) $pbp_3 = f\,(WPOILDZ)$

Production brute en prix constants / Gross production in constant prices

103) $pbr = io\_pb/pbp * 100$

5.7 ENERGY BALANCES (H)

5.7.1 MODELLING OF THE ENERGY BALANCE

The energy balance was limited to 4 energy source groups plus an additional column for renewables.

The basic assumption for energy balance modelling is that energy consumption as the sum of all energy sources depends on certain economic activities (such as an industry's gross output, GDP or private consumption).

The other variables are calculated by constant shares, reset to zero (or to the last available value) if they are very small and unpredictable, or they are determined as a sum (see Figure 17).

		cps	cpl	cpg	cpr	cpe	cet	
	Energy balance in ktoe	**Total solid products**	**Total liquid products**	**Total gas products**	**Renewables**	**Electricity**	**Total**	**Modelling**
1	**Production**	10	65000	100702		150	165861	exogenous
2	**Imports**	190	3873	0		126	4189	constant share of row 1 (production)
3	**Exports**	0	48597	59213		207	108017	sum of rows 1 and 2 minus 6
4	**Bunkers**	0	240	0		0	240	zero in the future
5	**Stock variation (production)**	-16	269	69		0	322	zero in the future
6	**Availabilities interior**	216	19767	41420		69	61472	equal to row 8
7	**Stock variation (consumption)**	-3	-51	28		0	-26	zero in the future
8	**Gross energy consumption**	220	19818	41391		69	61498	sum of rows 10 and 11 minus 9
9	**Transformation**	**-172**	**-3230**	**-16397**		**17743**	**-2056**	difference between rows 11 and 8 (for electricity); constant share of various rows
10	**Non-energy consumption**	**0**	**479**	**3007**		**0**	**3486**	constant share of row 8 (gross consumption)
11	**Net energy consumption**	**47**	**16109**	**21987**		**17812**	**55956**	sum of rows 12, 13, 29 and 30
12	**Industrial energy consumption**	**0**	**498**	**4575**		**1984**	**7057**	constant share of row 13 (final consumption)
13	**Final energy consumption**	**48**	**15338**	**15990**		**13270**	**44646**	sum of rows 14, 24 and 25
14	**Industry**	**45**	**710**	**4437**		**4750**	**9943**	sum of rows 15, 16, 18, 19, 22 and 23
15	**Building materials**	0	9	3356		1005	4370	ec = f (pbr8)
16	**Steel, metal, mechanical, electrical and electronic industries**	38	0	258		469	765	ec = f (pbr6)
17	Basic steel industry	38	0	258		103	399	share of row 16; sum of all columns (for total)
18	**Chemicals**	0	30	48		260	338	ec = f (pbr9)
19	**Manufacturing industries**	0	0	588		546	1134	sum of rows 20 and 21
20	Food industries	0	0	553		458	1011	ec = f (pbr10)
21	Textiles, leather, and clothing	0	0	35		88	123	ec = f (pbr11, TIMEL)
22	**Construction and public works sector**	0	356	4		81	441	ec = f (pbr8)
23	**Other industries**	7	315	184		2390	2895	ec = f (GDPTR)
24	**Transportation**	**0**	**14095**	**548**		**252**	**14895**	ec = f (GDPTR)
25	**Households and others**	**3**	**533**	**11004**		**8268**	**19808**	sum of rows 26, 27 and 28
26	Residential	3	0	9874		5126	15003	ec = f (HCESR, TIMEL)
27	Agriculture	0	16	66		358	440	ec = f (pbr1)
28	Tertiary sector and others	0	517	1063		2784	4364	ec = f (pbr15+pbr16+pbr17+pbr18)
29	**Losses**	**0**	**677**	**1159**		**2558**	**4394**	constant share of row 13 (final consumption)
30	**Statistical differences**	**-1**	**-404**	**264**		**0**	**-141**	zero in the future

Estimation | Constant share of another row | Constant share of total | Sum | Exogenous | Zero in the future

Figure 17: Energy balance for the year 2017 (reduced form)

Source: GWS on the basis of Ministère de l'Énergie (2018). ec = energy consumption

5.7.2 FINAL ENERGY CONSUMPTION

Estimates of total final energy consumption were made for different consumer groups. For distribution to energy sources, constant shares have been assumed. Renewable energies are added exogenously to the transformation sector (electricity production).

Industrie j / Industry j

$$cet_{15} = f\,(pbr_{8})$$
$$cet_{16} = f\,(pbr_{6})$$
$$cet_{18} = f\,(pbr_{9})$$
$$cet_{20} = f\,(pbr_{10})$$
$$cet_{21} = f\,(pbr_{11},\ TIMEL),\ with\ TIMEL = log(TIME - 1960)$$
$$cet_{22} = f\,(pbr_{8})$$
$$cet_{23} = f\,(GDPTR)$$

cet = last column of the energy balance

pbr = gross production at constant prices of the respective industry

Réduction de la consommation d'énergie par l'augmentation de l'efficacité énergétique / Reduction of energy consumption by increases in energy efficiency/

111) $rdeff_k$ = exogène (k = buildings / industry)

Impact de l'efficacité énergétique sur le secteur industriel / Impact of energy efficiency on the industry sector

112) $cet_{15} = cet_{15} - cet_{15} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

113) $cet_{16} = cet_{16} - cet_{16} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

114) $cet_{18} = cet_{18} - cet_{18} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

115) $cet_{20} = cet_{20} - cet_{20} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

116) $cet_{21} = cet_{21} - cet_{21} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

117) $cet_{22} = cet_{22} - cet_{22} / (cet_{15} + cet_{16} + cet_{18} + cet_{20} + cet_{21} + cet_{22} + cet_{23}) * rdeff_2$

Industrie sidérurgique de base/ Basic steel industry

118) $cps_{17} = cps_{16} * cps_{17}[lastdata] / cps_{16}[lastdata]$

119) $cpl_{17} = cpl_{16} * cpl_{17}[lastdata] / cpl_{16}[lastdata]$, if $cpl_{16}[lastdata] <> 0$; else $cpl_{17} = 0$

120) $cpg_{17} = cpg_{16} * cpg_{17}[lastdata] / cpg_{16}[lastdata]$

121) $cpe_{17} = cpe_{16} * cpe_{17}[lastdata] / cpe_{16}[lastdata]$

122) $cet_{17} = cps_{17} + cpl_{17} + cpg_{17} + cpe_{17}$

Transport / Transport

123) $cet_{24} = f\,(GDPTR)$

Résidentiel / Residential

124) $cet_{26} = f\,(HCESR, TIMEL)$

Impact de l'efficacité énergétique sur le secteur industriel / Impact of energy efficiency on the industry sector

125) $cet_{26} = cet_{26} - cet_{26} * rdeff_1$

Agriculture / Agricultures

126) $cet_{27} = f\,(pbr_1)$

Tertiaire et Autres / Tertiary economy and other

127) $cet_{28} = f\,(pbr_{15} + pbr_{16} + pbr_{17} + pbr_{18})$

Somme des fabrications / Sum of manufacturing

128) $cet_{19} = cet_{20} + cet_{21}$

same calculation for the individual energy sources

Somme de l'industrie / Sum of industry

129) $cet_{14} = cet_{15} + cet_{16} + cet_{18} + cet_{19} + cet_{22} + cet_{23}$

same calculation for the individual energy sources

Somme des ménages et autres / Sum of households and others

130) $cet_{25} = cet_{26} + cet_{27} + cet_{28}$

same calculation for the individual energy sources

Pertes / Losses

131) $cet_{29}[t] = cet_{13}[t] * cet_{29}[lastdata] / cet_{13}[lastdata]$

Écarts statistiques / Statistical differences

132) $cet_{30} = cps_{30} = cpl_{30} = cpg_{30} = cpe_{30} = 0$

Consommation finale / Final consumption

133) $cet_{13}[t] = cet_{14}[t] + cet_{24}[t] + cet_{25}[t]$

same calculation for the individual energy sources

Consommation industrielle énergétique / Industrial energy consumption

134) $cet_{12}[t] = cet_{13}[t] * cet_{12}[lastdata] / cet_{13}[lastdata]$

Consommation nette / Net consumption

135) $cet_{11}[t] = cet_{12}[t] + cet_{13}[t] + cet_{29} + cet_{30}$

same calculation for the individual energy sources

Consommation non énergétique / Non-energy consumption

136) $cet_{10}[t] = cet_{8}[t] * cet_{10}[lastdata] / cet_{8}[lastdata]$

137) $cps_{10}[t] = cet_{10}[t] * cps_{10}[lastdata] / cet_{10}[lastdata]$

138) $cpl_{10}[t] = cet_{10}[t] * cpl_{10}[lastdata] / cet_{10}[lastdata]$

139) $cpg_{10}[t] = cet_{10}[t] * cpg_{10}[lastdata] / cet_{10}[lastdata]$

140) $cpe_{10}[t] = cet_{10}[t] * cpe_{10}[lastdata] / cet_{10}[lastdata]$

individual energy carriers are calculated by constant share (from total consumption):
(for i = 12, 15, 16, 18, 20, 21, 22, 23, 24, 26, 27, 28, 29)

141) $cps_{i}[t] = cps_{i}[lastdata] / (cet_{i}[lastdata] - cpr_{i}[lastdata]) * (cet_{i}[t] – cpr_{i}[t])$

142) $cpl_{i}[t] = cpl_{i}[lastdata] / (cet_{i}[lastdata] - cpr_{i}[lastdata]) * (cet_{i}[t] – cpr_{i}[t])$

143) $cpg_{i}[t] = cpg_{i}[lastdata] / (cet_{i}[lastdata] - cpr_{i}[lastdata]) * (cet_{i}[t] – cpr_{i}[t])$

144) $cpe_{i}[t] = cpe_{i}[lastdata] / (cet_{i}[lastdata] - cpr_{i}[lastdata]) * (cet_{i}[t] – cpr_{i}[t])$

5.7.3 TRANSFORMATION

Electricité / Electricity

145) $cpe_8 = constant$

146) $cpe_9 = cpe_{11} - cpe_8$

Transformation (gaz, liquide, solide, renouvelable) / Transformation (gas, oil, solid, renewable)

147) $cpg_9 = cpg_9[lastdata]/cpe_9[lastdata] * cpe_9 - cpr_9$

148) $cpl_9 = cpl_9[lastdata]/cpl_8[lastdata] * cpl_8$

149) $cps_9 = cps_9[lastdata]/cet_{17}[lastdata] * cet_{17}$

150) $cpr_9 = cpr_1 * (-1)$

Transformation (total) / Transformation (total)

151) $cet_9 = cpe_9 + cps_9 + cpl_9 + cpg_9 + cpr_9$

Consommation brute / Gross consumption

152) $cet_8 = cet_{10} + cet_{11} - cet_9$

same calculation for the individual energy sources (except for cpe_8)

Disponibilités inter. / Availabilities interior

153) $cet_6 = cet_8$

same calculation for the individual energy sources

Production / Production

154) $cps_1[t]$, *exogène*

155) $cpl_1[t]$, *exogène*

156) $cpg_1[t]$, *exogène*

157) $cpe_1[t] = constant$

158) $cpr_1[t] = \sum_{k=1}^{6} hpc_k * inser_k$

159) $cet_1 = cps_1 + cpl_1 + cpg_1 + cpe_1 + cpr_1$

Importation / Imports

160) $cet_2[t] = cet_1[t] * cet_2[lastdata] / * cet_1[lastdata]$

same calculation for the individual energy sources

Exportation / Exports

161) $cet_3[t] = cet_1[t] + cet_2[t] - cet_6[t]]$ *(*cet_4 *and* cet_5 *do not have to be considered here, since they are set to 0 for the future)*

same calculation for the individual energy sources

Sautage / Bunkers

162) $cet_4 = cps_4 = cpl_4 = cpg_4 = cpe_4 = 0$

Variation stock (Prod.) / Stock changes (Prod.)

163) $cet_5 = cps_5 = cpl_5 = cpg_5 = cpe_5 = 0$

Variation stock (Cons.) / Stock changes (Cons.)

164) $cet_7 = cps_7 = cpl_7 = cpg_7 = cpe_7 = 0$

5.7.4 ENERGY PRICES

Prix du marché mondial / World market prices

165) *WPOIL = exogène*

166) *WPGAS = exogène*

167) *WPCOAL = exogène*

Prix du marché mondial en DZD / World market prices in local currency (DZD)

168) *WPOILDZ = WPOIL * EXRA*

169) *WPGASDZ = WPGAS * EXRA*

170) *WPCOALDZ = WPCOAL * EXRA*

Gaz: prix de vente / Gas user prices

171) $epgz_1 = f\,(WPGASDZ)$

172) $epgz_2 = f\,(epgz_1)$

173) $epgz_3 = f\,(epgz_1)$

174) $epgz_4 = f\,(epgz_1)$

Vecteur à 4 éléments: / Vector with 4 elements:

Haute Pression / high pressure
Moyenne Pression / medium pressure
Basse Pression / low pressure
Total / total

Table 5: Vector dimensions of "epgz"

Source: Own table.

Electricité: prix de vente / Electricity user prices

175) $epel_1 = f\,(epgz_1)$

176) $epel_2 = f\,(epel_1)$

177) $epel_3 = f\,(epel_1)$

178) $epel_4 = f\,(epel_1)$

Vecteur à 4 éléments: / Vector with 4 elements:

Haute Tension / high voltage
Moyenne Tension / medium voltage
Basse Tension / low voltage
Total / total

Table 6: Vector dimensions of "epel"

Source: Own table.

Produits liquides: prix de vente / Mineral oil products: user prices

179) $eppl_1[t] = eppl_1[t-1] * WPOILDZ[t] / WPOILDZ[t-1]$ *(fuel oil, industry)*

180) $eppl_2[t] = eppl_2[t-1] * WPOILDZ[t] / WPOILDZ[t-1]$ *(diesel)*

181) $eppl_3[t] = eppl_3[t-1] * WPOILDZ[t] / WPOILDZ[t-1]$ *(gasoline)*

5.8 EMISSIONS (H)

Charbon / Coal

182) $ecd_1 = fcd_1[2015] * (cps_8 - cps_{10} - cps_{12})$

Pétrole / Oil

183) $ecd_2 = fcd_2[2015] * (cpl_8 - cpl_{10} - cpl_{12})$

Gaz / Gas

184) $ecd_3 = fcd_3[2015] * (cpg_8 - cpg_{10} - cpg_{12})$

Total / Total

185) $ecd_4 = ecd_1 + ecd_2 + ecd_3$

Coefficient d'émission / Emission factors:

Charbon / Coal

186) $fcd_1[2015]$ = *exogène (assumption of long-term constant emission factors according to* CO_2 *content)*

Pétrole / Oil

187) $fcd_2[2015]$ = *exogène (assumption of long-term constant emission factors according to* CO_2 *content)*

Gaz / Gas

188) $fcd_3[2015]$ = *exogène (assumption of long-term constant emission factors according to* CO_2 *content)*

5.9 RENEWABLE ENERGIES AND ENERGY EFFICIENCY (I)

The purchase of renewable energy and expenditure on operations and maintenance, as well as expenditure to increase the energy efficiency of buildings and industry, lead to additional demand for all sectors of the economy.

Capacité de l'énergie renouvelable installée en MW, avec la distinction entre la fabrication et l'installation / RE capacity installed in MW, distinguishing between manufacturing and installation

189) $inser_k = exogène$

avec k = technologie (éolien, PV petit, PV grand, CSP, CES, biogaz) / technology (wind, PV small, PV large, CSP, CES, biogas)

Installations supplémentaires / fabrication supplémentaire d'énergie renouvelable / Additional installations / manufacturing of RE

190) $l = 1: ADER_{k,l}$: *exogène (manufacturing)*

191) $l = 2: ADER_{k,l} = inser_k[t]-inser_k[t-1]$ *(installations)*

Emploi direct des énergies renouvelables par MW en équivalents temps plein, par technologie et par niveau de la création de valeur / Direct employment from RE per MW in full time equivalents, by technology and value chain level

192) $EFER_{k,l} = exogenous$

Emploi direct des énergies renouvelables en équivalents temps plein, par technologie et par niveau de la création de valeur / Direct employment from RE in full time equivalents, by technology and value chain level

193) $l = 1$ *(manufacturing)*: $EMER_{k,l} = EFER_{k,l} * ADER_{k,l}$

194) $l = 2$ *(installations)*: $EMER_{k,l} = EFER_{k,l} * ADER_{k,l}$

195) $l = 3$ *(O&M)*: $EMER_{k,l} = EFER_{k,l} * inser_k$

Dépenses pour EE – le corps de bâtiment et l'industrie / Spending on EE – building envelope and industry

196) $SPGEE_{k,l} = exogenous$ *(k = building / industry)*

Emploi direct de l'efficacité énergétique par DZD en équivalents temps plein, par technologie et par niveau de la création de valeur / Direct employment from EE per DZD in full time equivalents, by technology and value chain level

197) $EFEE_{k,l} = exogenous$

Emploi direct de l'efficacité énergétique en équivalents temps plein, par technologie et par niveau de la création de valeur / Direct employment from EE in full time equivalents, by technology and value chain level

198) $l = 1: EMEE_{k,l} = EFEE_{k,l} * SPGEE_{k,l}$

199) $l = 2: EMEE_{k,l} = EFEE_{k,l} * SPGEE_{k,l}$

Prix pour les énergies renouvelables en DZD/MW, avec la distinction entre la fabrication et l'installation / Prices for RE in DZD/MW, distinguishing between manufacturing and installation

200) $PRER_{k,l}$ = *exogenous*

Part des dépenses annuelles d'exploitation et de maintenance par rapport aux dépenses d'installation passées / Share for annual spending on operation and maintenance relative to past installation expenditures

201) $opmac_k$ = *exogenous*

Dépenses pour ER / Spending on RE

pour k = 1,...,6:

202) $l = 1: SPGER_{k,l} = ADER_{k,l} * PRER_{k,l}$

203) $l = 2: SPGER_{k,l} = ADER_{k,l} * PRER_{k,l}$

204) $l = 3: SPGER_{k,l} = \sum_{i=0}^{t} SPGER_{i,k,2} * opmac_k$

Structure d'entrée pour les énergies renouvelables / Input structure for renewables

a. Fabrication / Manufacturing

205) $IPERM_{m,k}$ = *exogène (18 economic sectors, by technology)*

avec m = secteur / economic sector

	wind	PV small	PV large	CESP	CES	biogas
sector 1						
...						
sector 18						

Table 7: Dimensions of the matrices IPERM, IPERI, and IPERO

Source: Own table.

b. Installation / Installation

206) $IPERI_{m,k}$ = *exogenous (18 economic sectors, by technology)*

c. Exploitation et Maintenance / Operations & Maintenance (O&M)

207) $IPERO_{m,k}$ = *exogenous (18 economic sectors, by technology)*

Structure d'entrée pour mesures de l'efficacité énergétique / Input structure for energy efficiency measures

a. Fabrication / Manufacturing

208) $IPEEM_{m,k}$ = *exogenous (18 economic sectors, building / industry)*

	building	industry
sector 1		
...		
sector 18		

Table 8: Dimensions of the matrices IPEEM and IPEEI

Source: Own table.

b. Installation / Installation

209) $IPEEI_{m,k}$ *= exogenous (18 economic sectors, building / industry)*

Investissements (supplémentaires) dans les énergies renouvelables et l'efficacité énergétique / (Additional) investment in renewable energy and energy efficiency

210) $gferm = IPERM_{m,k} * SPGER_{k,l} (l = manufacturing) + IPERI_{m,k} * SPGER_{k,l} (l = installation) + IPERO_{m,k} * SPGER_{k,l} (l = O\&M)$

211) $gfeem = IPEEM_{m,k} * SPGEE_{k,l} (l = manufacturing) + IPEEI_{m,k} * SPGEE_{k,l} (l = installation)$

5.10 CLASSES

	Element number	Description
Supplying sector = receiving sector = economic sector	1	Agriculture, forestry, fishing
	2	Water and energy
	3	Hydrocarbons
	4	Public petroleum services and works
	5	Mining and quarrying
	6	Steel, metal, mechanical, electrical and electronic industries
	7	Building materials
	8	Construction, public works and hydraulics sector
	9	Chemicals, plastics, rubber
	10	Food industries
	11	Textiles, clothing, knitwear
	12	Leather and footwear
	13	Wood, paper, and cork
	14	Various industries
	15	Transport and communications
	16	Hotels, café, and restaurants
	17	Services provided to companies
	18	Services provided to households
Technology (RE)	1	wind energy
	2	PV small
	3	PV large
	4	CSP
	5	CES
	6	biogas
Techno-logy	1	building
	2	industry
Value chain level	1	manufacturing
	2	installation
	(3)	(O&M)

	Element number	Description
Row of energy balance	1	Production
	2	Imports
	3	Exports
	4	Bunkers
	5	Stock variation (production)
	6	Availabilities interior
	7	Stock variation (consumption)
	8	Gross energy consumption
	9	Transformation
	10	Non-energy consumption
	11	Net energy consumption
	12	Industrial energy consumption
	13	Final energy consumption
	14	Industry
	15	Building materials
	16	Steel, metal, mechanical, electrical and electronic industries
	17	Basic steel industry
	18	Chemicals
	19	Manufacturing industries
	20	Food industries
	21	Textiles, leather, and clothing
	22	Construction and public works sector
	23	Other industries
	24	Transportation
	25	Households and others
	26	Residential
	27	Agriculture
	28	Tertiary sector and others
	29	Losses
	30	Statistical difference

	Element number	Description
Emission source	1	coal, peat, and oil shale
	2	oil
	3	gas
	4	total
Pressure level	1	high pressure
	2	medium pressure
	3	low pressure
	4	total
Voltage level	1	high voltage
	2	medium voltage
	3	low voltage
	4	total
Oil product	1	fuel oil, industry
	2	diesel
	3	gasoline

Table 9: Classes of vectors or matrices in the model, English version

Source: Own table.

	Numéro d'élément	Description
Secteur	1	Agriculture, sylviculture, pêche
	2	Eau et énergie
	3	Hydrocarbures
	4	Services et travaux publics pétroliers
	5	Mines et carrières
	6	Industrie sidérurgique, métallique, mécanique, électrique et électronique (ISMMEE)
	7	Matériaux de construction
	8	Secteur du bâtiment, des travaux publics et de l'hydraulique (BTPH)
	9	Chimie, Plastiques, Caoutchouc
	10	Industries agro-alimentaires
	11	Textiles, confection, bonneterie
	12	Cuirs et chaussures
	13	Bois, Papiers et lièges
	14	Industries diverses
	15	Transport et communications
	16	Hôtels, cafés, restaurants
	17	Services fournis aux entreprises
	18	Services fournis aux ménages
Technologie (ER)	1	wind energy
	2	PV small
	3	PV large
	4	CSP
	5	CES
	6	biogas
Techno-logie	1	building
	2	industry
Niveau de la création de valeur	1	manufacturing
	2	installation
	(3)	(O&M)

	Numéro d'élément	Description
Ligne du bilan énergétique	1	Production
	2	Importation
	3	Exportations
	4	Soutages
	5	Variation de stock (production)
	6	Disponibilités intérieur
	7	Variation de stock (consommation)
	8	Consommation brute
	9	Transformation
	10	Consommation non énergétique
	11	Consommation nette
	12	Consommation industrielle énergétique
	13	Consommation finale
	14	Industrie
	15	Matériaux de construction
	16	Industrie sidérurgique, métallique, mécanique et électronique(ISMME)
	17	Sidérurgie de base
	18	Chimie
	19	Industries manufacturières
	20	Agroalimentaire
	21	Textiles, cuir et habillement
	22	Secteur du bâtiment et des travaux publics (BTP)
	23	Autres industries
	24	Transports
	25	Ménages et autres
	26	Résidentiel
	27	Agricultures
	28	Tertiaire et autres
	29	Pertes
	30	Écart statistique

	Numéro d'élément	Description
Source des émissions	1	charbon
	2	pétrole
	3	gaz
	4	total
Niveau de pression	1	haute pression
	2	moyenne pression
	3	basse tension
	4	total
Niveau de tension	1	haute tension
	2	moyenne tension
	3	basse tension
	4	total
Produits liquides	1	fuel oil, industrie
	2	gasoil
	3	essence

Table 10: Classes of vectors and matrices, French version

Source: Own table.

6 APPENDIX C: USER MANUAL

The model is fully implemented in MS Excel and easily accessible via one single file that includes all data, functions and routines. e3dz.xlsm is used to run the model, it enables the modification of scenarios and updating of data, and it provides the results of all calculation routines for all variables as output.

Just as a broad overview, the model is run from the worksheet "Model", all data is stored and can be updated on the worksheet "Values" and output is transferred to "Results" once the calculations are completed; "Dataset" stores all variables and their descriptions (sorted by variable type and in alphabetically descending order); Scenarios can be created using the sheet "Scenario" (for more details on the respective worksheets see 7.3).

The following quick guide deals with the most typical user activities.

6.1 RUN THE MODEL

To start the calculation and run the model with current specifications, the "Run" button on the worksheet "Model" has to be clicked. The model then calculates iteration by iteration for all specified years. The number of iterations required for each year until the convergence criteria is reached (see chapter 7.2) is also documented in column B on the same sheet (see Figure 18). Start year and end year of the model run can be set in cells B1 and B2, respectively. The minimum start year is 2000, the maximum end year 2050.

The maximum number of iterations in a single year can also be set on the worksheet "Model" (cell B3). Please note that this parameter in most cases shall not be modified and only serves as a safety net in case of an unstable, not converging model, in which the number of iterations becomes infinitely large. Reaching the default value of the number of maximum iterations (100) is considered as a clear indicator that the underlying model or scenario has been misspecified. Therefore, in such a case, the calculation routine is terminated.

Important hint

To ensure that the calculation can be performed as quickly as possible all other Excel files should be closed before starting the model.

When the iterations of the model are completed, all results are given on the "Results" worksheet in the order of their appearance on the "Dataset" worksheet. This raw output can then further be processed for a more intuitive overview and comprehensive tables and graphs (see 6.5).

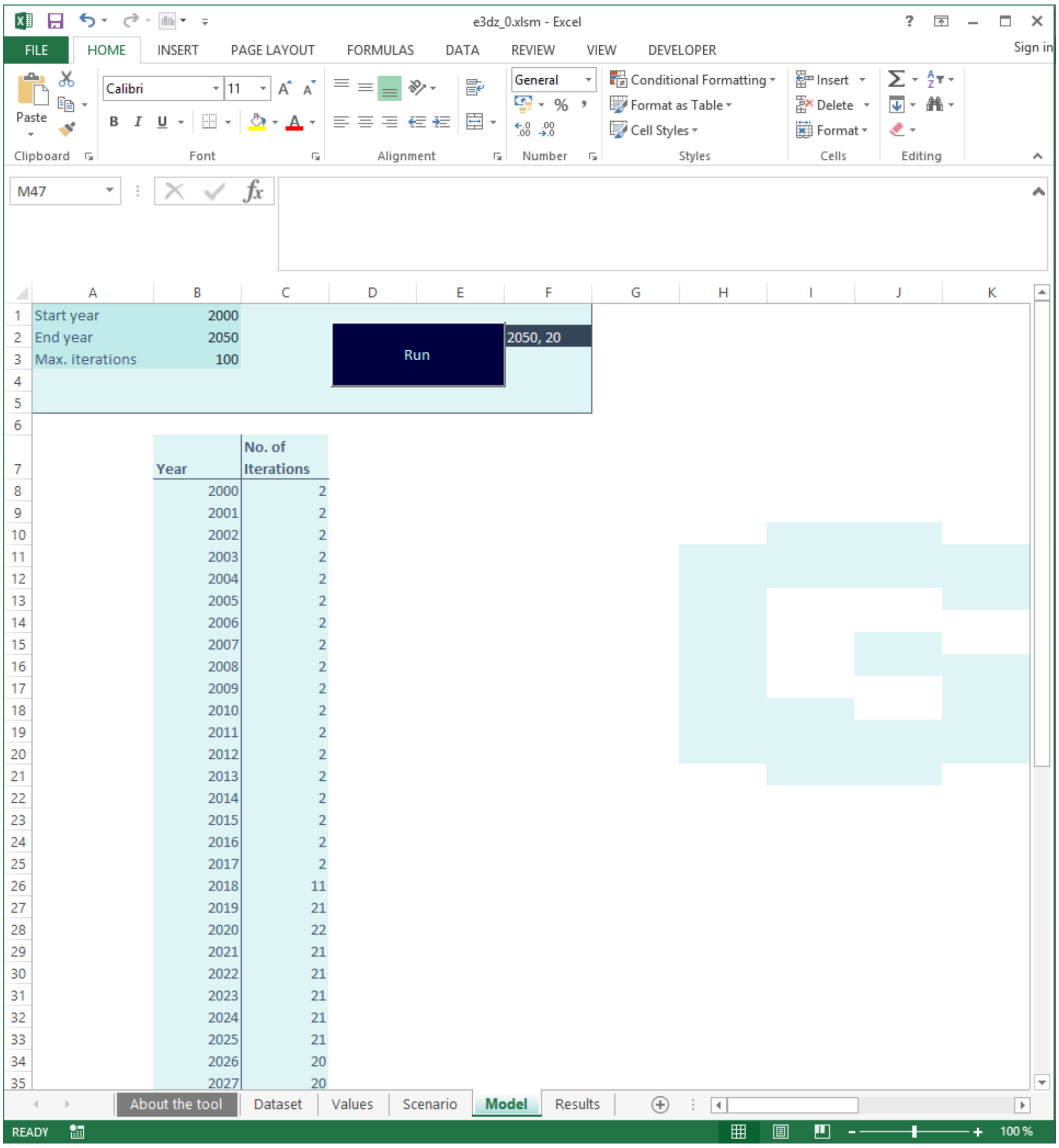

Figure 18: "Run" button on the Excel sheet "Model"

Source: Own screenshot of MS Excel.

6.2 CREATE SCENARIOS

Scenarios are created by modifying certain key variables using the "Scenario" worksheet via so called tweaks. In general, all values can be modified that are either result of a regression or enter the model exogenously. Variables that result by definition cannot be adjusted – otherwise the consistency of the model would be compromised. Which variables can and cannot be altered can be seen in detail on the "Dataset" worksheet; in certain cases this is different for individual elements of a vector or matrix.

On the "Scenario" worksheet, each tweak over time can be entered in one Excel row and is assigned to a variable by referencing its name (column C). For elements of vector variables the respective row is required (and entered in column D). In the case of a matrix variable, both row and column position (column E) are to be entered.

Tweak type	Functioning of the tweak	Example
AAGR	The last value is projected with the given annual average growth rate.	Last value in t: 100, AAGR-tweak in t+1: 3 → result in t+1: 103
CTA	The given value is added to the value estimated in the model (CTA = Constant Term Added).	Model value: 100, CTA-tweak: 30 → result: 130
MUL	The values estimated in the model are multiplied by the given factor.	Model value: 100, MUL-tweak: 1.5 → result: 150
OVR	The model values are overwritten with the given values.	Model value: 100, OVR-tweak: 110 → result: 110

Table 11: Tweak types

Source: Own table.

There are four different ways a value can be modified. Table 11 shows the different tweak types that cover a wide range of possibilities. With AAGR and OVR, any existing values are overwritten, whereas the CTA or MUL tweaks build upon the estimated model values by adjusting them.

Finally, the corresponding tweak values can be entered for individual years (columns G to AU). When choosing values, the scope of the values should reflect their respective tweak type to ensure model stability. Blank years in the Scenario sheet in between values are filled by linear interpolation in the model.

Independent of entries on the "Scenario" worksheet, historical values cannot be altered in any way. Which is a historical value and which is not is determined by the "lastdata" entry on the "Dataset" worksheet. All values up to and including the "lastdata" point in time are considered historical (also see section 7.3).

All tweaks can be enabled and disabled individually, using an „x" in the first column of the scenario sheet to activate them.

Figure 19 shows the tweak setting for the world market price of oil for the period 2040 to 2050, that is an overwrite tweak. Only 2040 and 2050 have been entered, the blue figures for the interim years result from linear interpolation.

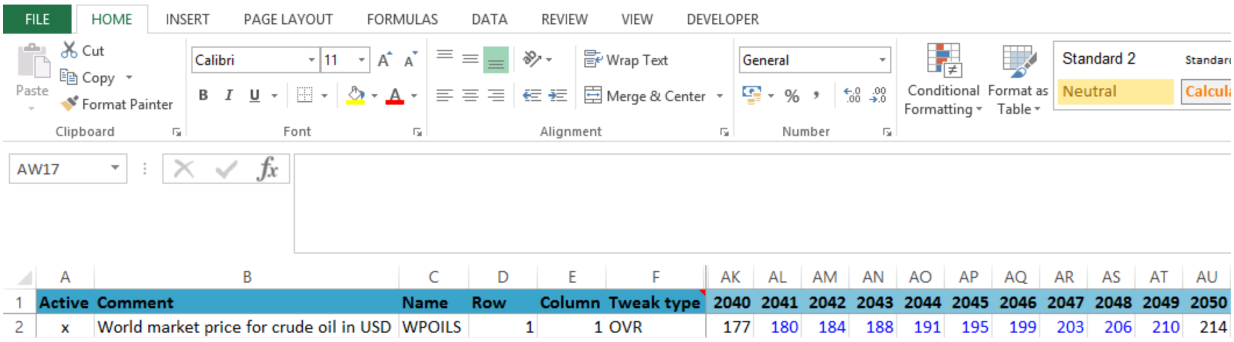

Figure 19: Example of an OVR tweak for oil price

Source: Own screenshot of MS Excel.

6.3 EDIT DATA

Values of existing time series can be updated and new time series and variables can be added to the model at any time. Updating includes both, the revision of older data by replacing the respective values and adding the most recent values to time series.

When revising old data, the values can simply be changed on the "Values" worksheet. If the time series is not extended further into the recent past, the model can immediately be run and takes into account all changes made. When modifying historical data it is of major importance to keep their unit consistent with previous entries (see column H "Unit" on the "Dataset" worksheet).

When data are updated and one or several new years are added to a time series, those can be added on the "Values" worksheet as well. However, with the date of the most recent data point changing, an adjustment of the "lastdata" entry of the corresponding variable is necessary and can be done by adjusting column D on the sheet "Dataset". This entry determines which years of a time series are historical (and can e.g. thus not be altered by tweaks) and which are not (and are e.g. thus projected into the future by a regression model). This change affects the structure of the data and necessitates an update of the complete dataset. To update the dataset, the VBA code containing declarations and other settings has to be updated. To do this, open the VBA code (Figure 20; please make sure developer tools are enabled in the option bar settings) and delete the outdated dataset module (Figure 21).

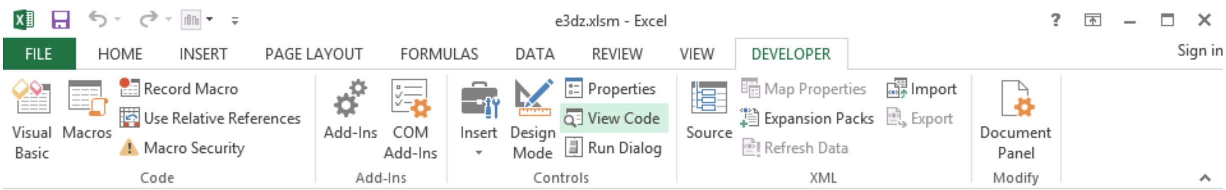

Figure 20: Button in the Excel tool bar to open the VBA code

Source: Own screenshot of MS Excel.

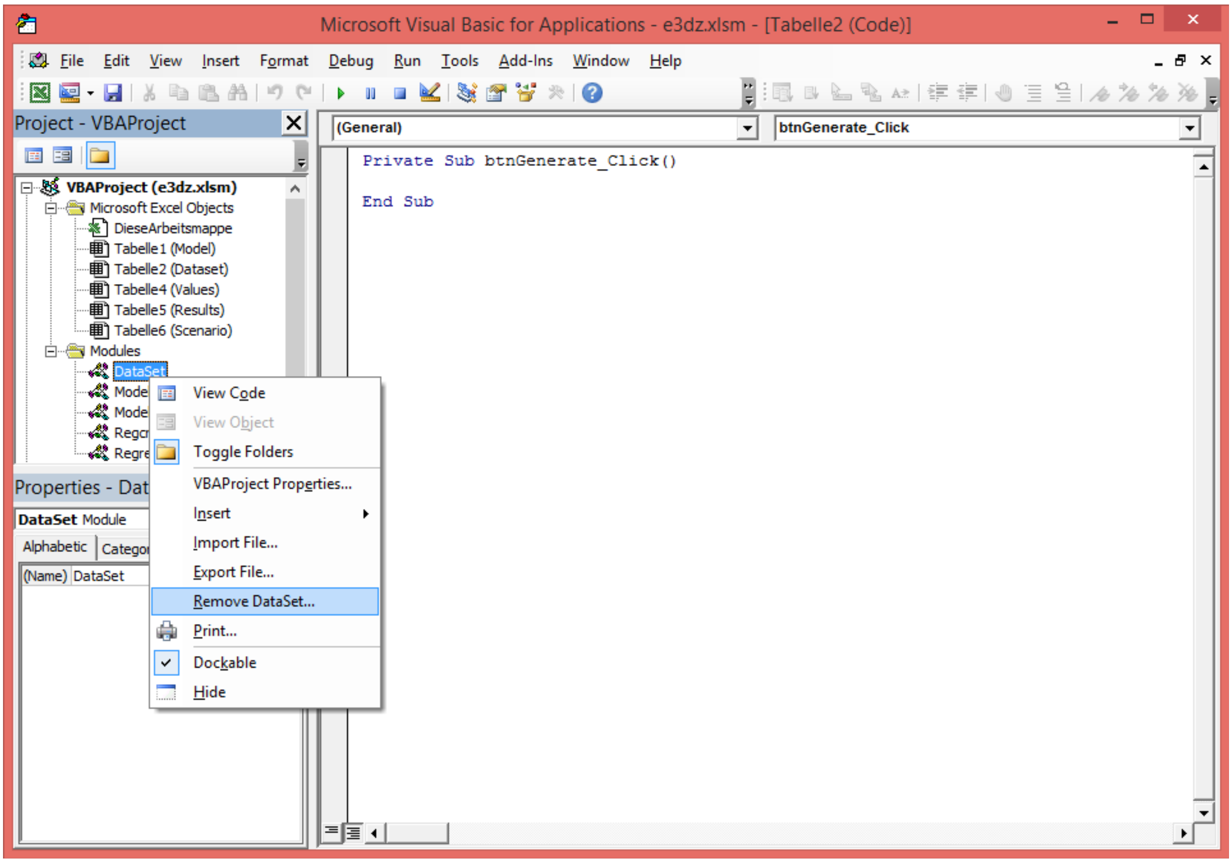

Figure 21: Removing an existing "DataSet" module

Source: Own screenshot of MS Excel.

Pressing the „Generate" button on the Excel sheet "Dataset" (Figure 22) automatically generates a new Dataset module that includes all relevant information and can be processed by Excel. This module is created as a batch file named „DataSet.bas" in the folder where the model is located and has to be reimported in the VBA Project under „Modules" (Figure 23).

With the new dataset imported, the model can be run as before.

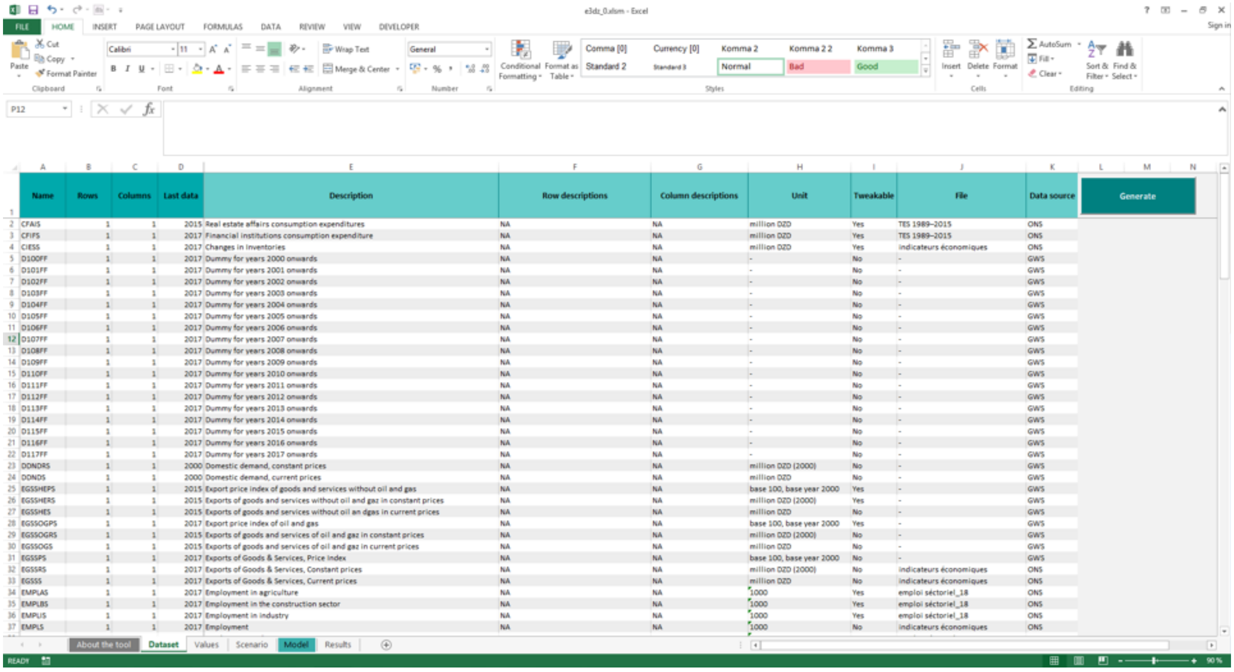

Figure 22: Generate" button on the Excel sheet "Dataset"

Source: Own screenshot of MS Excel.

In case a new variable is created that has previously not existed in the model, this variable has to be described in the worksheet "Dataset". Each variable uses a unique name that is different from all other variables (column A). Default convention is that the name of scalars is in caps and ends in an "S", vectors' names are in lower case letters and end in a "v", and matrix variables are written in caps and end in an "M". Furthermore the dimensions of the variable need to be specified, i.e. the total number of rows and columns of vectors and matrices (column B and C; for scalars both are equal to 1, as are columns in the case of a vector variable). Lastdata (column D) is set to the last point in time for which data of the variable is available (in the case of vectors and matrices: last point in time for which data for all their elements are available). All other columns on the "Dataset" worksheet are for information only and do not have to be filled – although it is highly recommended to do so.

The variable can then be entered on the "Values" worksheet. In the case that historical data exist, each element, i.e. each combination of row and column, is entered into an individual row up to the point in time equal to the "lastdata". If no historical values exist, there is no need to include the variable on the values sheet. Please keep in mind that even if no historical values exist, the lastdata of a tweakable variable, i.e. when its tweak function is called in the model code, is to be set to 2010 or later.

Since the creation of a variable is a major dataset modification, the dataset has to be updated following the steps described above (deletion of the old dataset, generation and implementation of the new one). Again, with the new dataset imported, the model can be run as before.

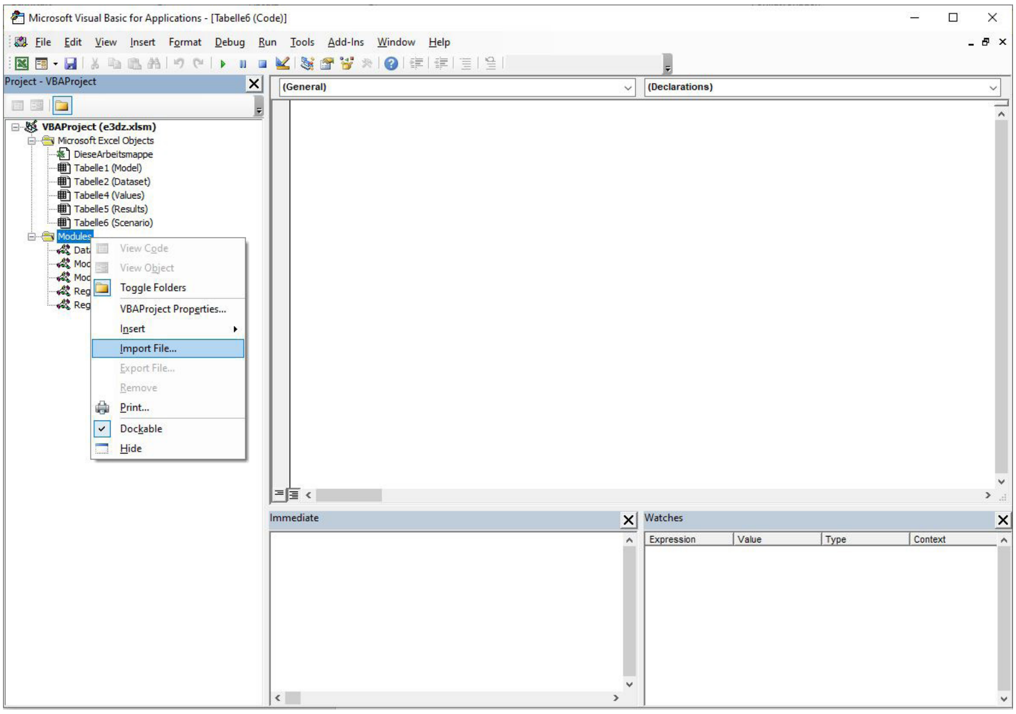

Figure 23: Importing of "DataSet.bas"

Source: Own screenshot of MS Excel.

6.4 IMPLEMENT NEW OR MODIFIED REGRESSION EQUATIONS

The model contains definitions and regressions. The definitions are always valid and should not be changed. In the case of regressions, a regular adjustment is advisable, e.g. to test a new estimation approach or when more data are available in the respective time series. The estimation can be calculated with any standard regression software. The new regression equation must be implemented in the VBA code by replacing the old equation in the module "Model" or "Regressions".

The currently existing regression equations in the model are logarithmized. Since logarithms on the left side of equations cannot be processed in the VBA code, logarithmic equations must be transformed as follows:

$$\log y(t) = b_0 + b_1 * \log x_1(t) + \ldots + b_n * \log x_n(t)$$
$$y(t) = \mathrm{Exp}\,[b_0 + b_1 * \log x_1(t) + \ldots + b_n * \log x_n(t)]$$

with y = dependent variable
b_0 = intercept
$b_1, b_2, \ldots, b_n$ = coefficients
$x_1, x_2, \ldots, x_n$ = regressors
t = time

When severely modifying regressions, e.g. by adding new, previously not used regressors, it is of major importance to take into account interdependencies. Variables that are referred to ought to have calculated previously in the same iteration. If this leads to the necessity of changing the order of regressions, it might influence the stability of the model.

6.5 OVERVIEW OF RESULTS AND COMPARISONS OF SCENARIOS

Since the standard output includes all data that is processed by the model and is neither sorted by relevance nor prepared in any way, an additional Excel tool gives a comprehensive overview and facilitates the comparison of multiple previously calculated scenarios.

In general, to store a variety of different scenarios it is advised to save the model after completion of a scenario run under a new file name. Our recommended practice is to add the title of a scenario to the file name of the model, separated by an underscore (e.g. e3dz_0.xlsm, with 0 always indicating the reference scenario). If multiple scenarios exist and are saved in the above suggested manner, their respective outputs can be collected in one file using the tool ScenCompare.xlsm. With all Excel files of the respective scenarios and the file ScenCompare.xlsm stored under the same file path, the names of the scenario files can be added on the "Menu" worksheet of the ScenCompare file. Pressing the "Load Data" button copies the individual result sheets into the file. They are stored on individual worksheets with a name consisting of "Scen_" and the respective scenario name.

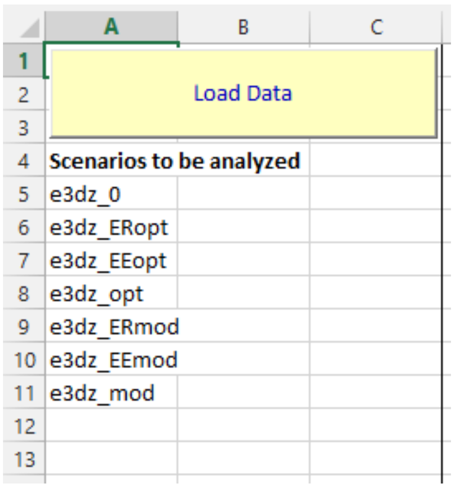

Figure 24: Consolidating data of different scenarios

Source: Own screenshot of MS Excel.

The worksheet “Overview” yields a comprehensive overview of the difference between two selected scenarios. Entering their titles in cells B1 and B2, respectively, fills a number of preformatted tables that comprise thematically close variables.

The worksheet “Comparison” enables a detailed look on freely chosen variables (or elements of variables) of one or more selected scenarios. Again, scenario titles are to be entered into cells B1 and B2. Up to four variables can then be selected by filling the grid in the range E1:G4. Beyond the name of the variable, row and column position of its element that is of interest are necessary specifications.

	A	B	C	D	E	F	G	H
1	**Scenario 1:**	0			GDPTRS	1	1	
2	**Scenario 2:**	EEopt			EGSSHERS	1	1	
3					pbrv	3	1	
4					EMPLS	1	1	
5								

Figure 25: Specifying variables of interest

Source: Own screenshot of MS Excel.

In the table close to top of the worksheet, average growth rates of all specified variable elements are displayed, followed by a graph that is rather customizable. By selecting the type of presentation in cell B20, the user has the option to view variable elements as absolute values, as a calculated index with a selectable base year (cell F20), or obtain their respective growth rates relative to the preceding year. The table underneath the diagram adjusts accordingly, stating the underlying data in five year intervals.

Finally, on the bottom of the worksheet a diagram showcasing the differences between the scenarios (in case two have been selected) follows. Since this type of comparison is limited to one variable for optical reasons, the variable of interest can be selected by entering its respective position in the list of variables into cell B20.

7 APPENDIX D: TECHNICAL DESCRIPTION OF THE MODEL

7.1 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 a dynamic IO model as long as at least the following features are provided.

A dynamic IO model is processing data over time; thus the language has to support multidimensional data structures. These are called array in most programming languages. Some languages such as Python do not have a built-in array type. This is not a problem as long as programming libraries are available which offer array-like data structures (for Python, a well-known library for numeric data processing is named "Numpy" www.numpy.org). In some languages, array-indexing is zero-based (C, C++) whereas in other languages the first element in an array has the index one. The latter is preferable since most of the published data and sector classifications use one-based indices.

Array-like data structures are not only necessary to process data over time but also to handle data which contains more than one value per year (e.g. sectoral data, IO matrices). For most use-cases, three-dimensional structures are sufficient, i.e. to store a sequence of IO matrices. The speed of indexing into arrays greatly differs between programming languages and is quite important because a comprehensive dynamic IO model contains a considerable amount of these statements. The following table shows the processing time for setting each element in a 10,000x10,000 double-precision floating point array in some popular programming languages[3]. The most simple built-in array implementation in each of the languages was used to receive comparable results.

Interpreted languages are the slowest because instructions are processed one-by-one without much room for optimizations. Compiled code performs fastest because the program as a whole is translated into machine-executable form and usually highly optimized. JIT (Just In Time)-compiled code is often almost as fast as compiled code by translating the program into an intermediate, processor-independent code which is then translated into processor-dependent code at runtime. The table shows that Excel`s built-in VBA language – although it is an interpreted language – performs more than acceptable in comparison to other languages.

3 The size was chosen to simulate a comprehensive model with a lot of indexing statements. The calculation was done using an Intel i7-8600k processor with 32GB RAM. The code is available on request.

Language	Time (s)	First Index	Language type
EViews 9	93	1	Interpreter
Octave 5.1	435	1	Interpreter
R 3.6.1	2628	0	Interpreter
Python 3.6	54	0	Interpreter
Julia 1.0	4.5	1	Interpreter
VBA 2016	**5**	**1**	**Interpreter**
VBScript 5.812	19	0	Interpreter
C# Interactive 3.1	0.5	0	JIT Compiler
Java JDK 1.8	0.2	0	JIT Compiler
C# .NET 4.7	0.6	0	JIT Compiler
MinGW C++ 7.3	0.3	0	Compiler

Table 12: Processing time for array element processing (10k x 10k elements) in selected programming languages

Source: Own calculations.

Additional essential features which are provided by almost every programming language including VBA are

- loops to be able to iterate over time as well as to address elements in a multi-dimensional data structure,
- conditional statements to differentiate cases in order to be able to execute different branches of code,
- sub-programs (functions, procedures) to create reusable subroutines and
- modules to divide a program into logical parts (see section 7.4).

A few programming languages support matrix and vector algebra (e.g. Matlab, Octave) which makes equation statements much more readable. For languages lacking this feature – VBA belongs to this group –, matrix and vector algebra must be implemented by using "functions".

In order to track down errors, a debugger is extremely useful: Code may be halted at any statement (often called break) as well as data may be evaluated at run-time when the program has been interrupted by a "break" instruction. Some debuggers even allow for evaluating expressions while the program is in interrupted state. MS Excel has a built-in debugger which supports these features.

In summary, it can be stated that MS Excel meets the requirements for building comprehensive macroeconomic dynamic IO models.

7.2 MODEL FRAMEWORK

e3dz is built on top of a model building framework developed in pure VBA offering the following features:

Self-contained: The full model containing the data (both historical and projected), programming statements and scenario specifications is stored in one MS Excel workbook which simplifies both setup and distribution of the model.

User-friendly: The framework offers dedicated worksheets for data definition, historical and projected data, scenario definition and model execution. Operating the model does not require any programming skills (see section 7.3).

Integrated iterative solving algorithm: Comprehensive dynamic IO models can usually not be solved explicitly if the number of equations and the number of variables are equal. Thus, an iterative solving algorithm such as Gauss-Seidel is needed. In the framework, the *model* module (see section 7.4.2) contains all equations explicitly written in readable form, e.g.

WAGE(t) = WAGEC(t) * EMPL(t).

In each year, a user-defined subprogram *Calculate* containing the model equations is called by the framework iteratively.

At the end of each iteration, the framework calls the user-defined function *hasConverged*. Convergence is accomplished if the deviation between two iterations for a certain variable (e.g. GDPTR: Gross Domestic Product, Constant Prices) is less than a given threshold. If the threshold is exceeded, *Calculate* is called again, otherwise the algorithm proceeds with the next year. The framework stops execution of the model prematurely if a user defined number of iterations is exceeded in order to avoid endless looping. A slightly simplified version of the iterative solving algorithm is shown in the following figure:

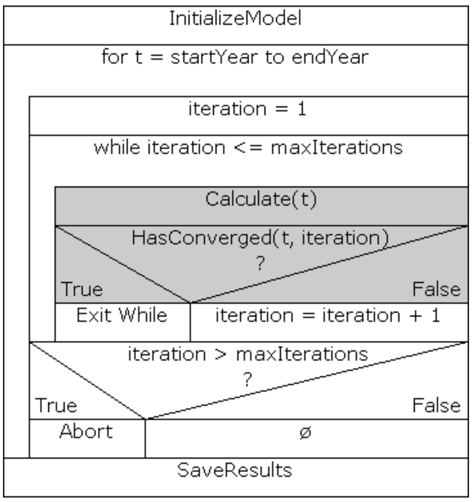

Figure 26: Iterative solving algorithm

Source: Own figure.

The grey boxes describe the user defined functions which have to be provided by the model builder.

The iterative solving algorithm is embedded in the subroutine *Run* (see module *model* in section 7.4.2).

7.3 EXCEL SHEETS

The framework contains five worksheets which simplify interaction with both model builders and model users which may use the model only for policy analysis.

Dataset

The sheet *Dataset* contains the definition of all endogenous and exogenous model variables. Some information (columns 1 to 4) is essential for the operation of the model whereas the remaining columns 5ff contain meta information to describe a variable in greater detail (e.g. description, unit, data source). The first column Name contains the variable name. The suffix of the name and the number of Rows and Columns indicate the data type (S = scalar, v = vector, M = matrix) of the variable. The column *Lastdata* contains the year for which the last value is available. This information is needed to prevent historical data from being overwritten at model run time.

In addition, the column *Tweakable* indicates whether a variable's values may be tweaked exogenously (see sheet *Scenario*). As an example, Figure 27 shows the definition for the vector io_egssv.

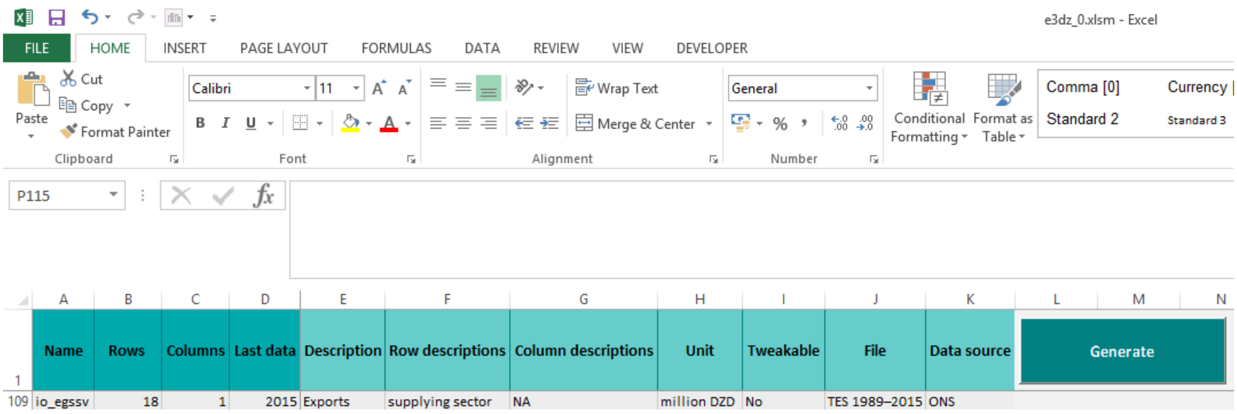

Figure 27: Example for a variable definition in the *Dataset* sheet

Source: Own figure.

Any change to the dataset requires rebuilding of the VBA variable declaration statements. The framework carries out the necessary steps automatically by pressing the *Generate* button on the *Dataset* sheet (see section 6.3).

Values
The *Values* sheet contains the historical data – if available – for all model variables which are defined in the *Dataset* sheet. The column *Name* contains the variable name as defined in the *Dataset* sheet. For multi-dimensional variables, the values of the *Row* and *Column* columns indicate the position. In the model code, the *Lastdata* value should be checked in order to prevent historical data from being overwritten. The remaining columns contain the annual values.

Model
The *Model* sheet is used to initiate model execution by pressing the *Run* button. Model execution may be fine-tuned by adjusting the values of *Start year, End year* and *Maximum iterations*. It must be pointed out that the model may become unstable if any of the values deviate from ranges set by default.

Scenario
Variables which are considered exogenous in the model context may be altered (*tweaked*) at model runtime. The framework replaces the calculated values by the values given in the sheet *Scenario*. In general, all exogenous variables and those calculated by regressions can be tweaked.

It is not necessary to enter a value for each year; empty cells in between values are filled by linear interpolation. To activate a tweak, an „x" must be set in the first column (see section 6.2).

Results
If model execution succeeded without any error, the full dataset (historical and calculated values) is written to the sheet *Results*. Variables which are not explicitly calculated in the model code are kept constant for the years after the given *Lastdata* value in the sheet *Dataset*.

7.4 MODULES

7.4.1 DATASET

This module contains declarations in the VBA programming language for all variables which have been defined in the sheet *Dataset*. The content is created automatically by pressing the *Generate* button at the top of that sheet.

For each variable, the framework also generates a constant containing the *Lastdata* value which denotes the last year of available historical data. This value is referred to in the model code in order to avoid historical data from being overwritten in the model equations.

The following code fragment shows what the framework generates for each variable:

Public YNM (1996 To 2050,1 To 18,1 To 18) As Double
Public Const YNM_lastData = 2015

Furthermore, the module contains subroutines for automatically updating a variable, i.e. keeping its values constant if it is not explicitly calculated in the model code. This feature is extremely important: Without it, variables which have no equation yet could not appear in other equations because – due to the missing values – all kinds of arithmetic errors would occur.

The content of the module *Dataset* should not be edited manually because the content is fully rewritten after the *Generate* button has been pressed.

7.4.2 MODEL

This module is the core of the model. It contains both the model logic of the framework and the model-specific equations and statements.

The subroutine *Run* implements the iterative solution algorithm (see Figure 26) which is executed after the user has clicked the *Run* button on sheet *Model*.

As mentioned in section 7.2, the model builder needs to provide two subroutines: The function *HasConverged* is needed to implement the convergence criteria. The subroutine *Calc* contains all equations and other model-specific statements.

In order to increase readability, the model code should be further divided into subroutines. For e3dz, the following subroutines were defined:

- Sub ExoTweak(ByVal t):
  Tweaking of all exogenous variables that are not determined by regression or definition
- Public Sub gdpCalc(ByVal t):
  Calculation of oil and gas related GDP and GDP without oil and gas
- Public Sub pbCalc(ByVal time):
  Calculation of gross production (pb) in each sector vector using the Leontief inverse
- Public Sub ynCalc(ByVal time):
  Calculation of the matrix for intermediate inputs (YN) in the input-output table
- Public Sub ucCalc(ByVal time):
  Calculation of unit costs (uc) in each sector
- Public Sub pbpCalc(ByVal time):
  Calculation of production prices (pbp) in each sector
- Public Sub mcCalc(ByVal time):

Calculation of commercial margins (mc) in each sector

- Public Sub empCalc(ByVal t):
  Calculation employment in agriculture (EMPLA), in the construction sector (EMPLB), in industry (EMPLI), and in the service sector (EMPLS)
- Sub ebCalc(ByVal t):
  Calculation of the energy balance in the separate columns (cps, cpl, cpg, cpe, cpr, cet)
- Public Sub io_hcesCalc(ByVal time):
  Calculation of household consumption expenditure by demand sector
- Public Sub reCalc(ByVal time):
  Calculation of expenditures and employment for renewable energy
- Public Sub eeCalc(ByVal time):
  Calculation of expenditures and employment for energy efficiency
- Public Sub emiCalc(ByVal t):
  Calculation of CO2 emissions using constant emission factors
- Public Sub epCalc(ByVal t):
  Calculation of energy user prices for gaz, electricity, and oil products
- Public Function MatMul3_2_3_1(ByVal time, ByVal MatA, ByVal MatB, ByVal colB):
  Function for matrix multiplication

7.4.3 MODELTOOLS

This module contains various subroutines to provide functionality which is not to be found in the MS Excel programming libraries, i.e. subroutines related to matrix algebra, implementation of the tweaking mechanism and model initialization routines. The subroutines avoid redundancies and are called from various routines, i.e. the iterative solving algorithm, in the *Model* module. *Modeltools* contains the following subroutines:

- Public Function GetArrayDim(Arr As Variant) As Integer:
  Gets the dimension of a multi-dimensional array
- Sub UpdateSeries(ByVal t As Integer, ByVal lastData As Integer, ByRef var() As Double):
  Updates a series by setting current year's value to last year's value if given year t is after lastData
- Public Sub GenerateDataBase():
  Creates the module *DataSet.bas* which contains all variable declarations (and support routines) as defined in the *Dataset* sheet
- Public Sub AssignArray(ByRef dest() As Double, ByRef src As Variant):
  Assigns values of a (multidimensional) variant to a (multidimensional) array of doubles
- Public Sub InitializeHistoricData():
  Assigns contents of the Values sheet to the appropriate variables
- Sub SaveResults():
  Saves results to *Results* sheet after model has been executed successfully

- Public Function MatRowSum(ByVal matrix, ByVal time, ByVal row):
  Calculates a row sum of a matrix
- Public Function MatColSum(ByVal matrix, ByVal time, ByVal col):
  Calculates a column sum of a matrix
- Public Sub InitializeTweaks():
  Processes the tweaks as defined in the *Scenario* sheet
- Public Sub Tweak(ByVal t As Integer, ByVal lastData As Integer, ByVal varName As String, Optional ByVal row As Integer = 0, Optional ByVal col As Integer = 0):
  Applies a tweak for given year, variable (and position if variable is multi-dimensional). Tweak is ignored if year t is before variable's lastdata in order to prevent historical data from being overwritten.
- Public Function tweakCheck(ByVal varName As String):
  Checks whether the respective variable is tweaked in the *Scenario* sheet

7.4.4 REGRESSIONS

This module includes definitory equations that are related to vector elements and regressions. Before they are executed, an if condition is used to check whether the current year is past the lastdata so that the historical data is not overwritten. Regressions are not exclusively found in the regression module. In some cases, i.e. when they are highly interdependent and intertwined with definitory equations, regressions are grouped in calculation sub routines. These can be found in the module "Model" as described above.

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