Integrated Systems Analysis:

Belgium's SDG performance under Business As Usual scenario

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Abstract

In 2015, Belgium confirmed their political willingness to commit to sustainable development by adopting United Nations' 2030 Agenda and the 17 Sustainable Development Goals it undermines. While the deadline to achieve the goals is getting closer, literature suggests that Belgium is not on track to meet them. Moreover, even though the United Nations suggest using systemic and integrated methods of planification, Belgium is still lacking the institutional knowledge and tools to align themselves with these guidelines. It's in this context that this thesis aims to fill in the methodological gap and provides an analysis of a Business As Usual (BAU) scenario to better understand the trajectory Belgium is undertaking.

Using the well founded iSDG system dynamics model of the Millennium Institute, this study presents the integrated nature of such a computer simulation tool by highlighting its causal and feedback rich structure so that its capacities in the decision making process are clearly delineated. After which I describe methodologically how the model is adapted and validated for Belgium's context. Based on the model's calibration process, the study discusses the future work that could be performed in the model structure so the societal debate that surrounds sustainable development in Belgium is better covered by the model.

Finally, the BAU scenario analysis serves as a first iteration in the process of understanding the dynamics that might unfold. In that regard, it warns about the potential negative effects of economic growth on environmental sectors and the increasing gap of social inequalities.

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List of abbreviations

BAU	Business As Usual
BFP	Bureau Fédéral du Plan
CIDD	Commission Interdépartementale pour le Développement Durable
CLD	Causal Loop Diagram
COFOG	European Classification Of the Functions Of Government
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Green House Gas
ICN	Institut des Comptes Nationaux
IEA	International Energy Agency
IFDD	Institut Fédéral pour le Développement Durable
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
iSDG	Integrated Sustainable Development Goals
ISM	Integrated Systems Models
LCU	Local Currency Units
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
NBB	National Bank of Belgium
OECD	Organisation for Economic Co-operation and Development
PM	Particulate matter
RLCU	Real Local Currency Units
RME	Raw Material Equivalents
RMSPE	Root Mean Square Percent Error
SD	System Dynamics
SDG	Sustainable Development Goals
T21	Threshold 21
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WDI	World Development Indicators
WHO	World Health Organization

Chapter 1: Introduction

1.1 Background

In 2015, all Member States of the United Nations voted on the 2030 Agenda for Sustainable Development (United Nations, 2015). The centrepiece of this agenda is the 17 Sustainable Development Goals (SDGs), demanding prompt action from all countries, regardless of their level of development. These goals acknowledge that addressing inequalities or climate change issues requires implementing strategies that enhance health and education, stimulate economic progress, tackle poverty, ensure sustainable resource management, all while entailing international cooperation. The present research seeks to analyse in an integrated and systemic fashion Belgium's SDG performances.

Whilst Belgium didn't wait until 2015 to set a long term vision for sustainable development (Chambre des Représentants de Belgique, 2012; IFDD, 2013), the latest *Rapport Fédéral sur le Développement Durable* conducted by the *Bureau Fédéral du Plan* (BFP) keeps alarming that the efforts are not sufficient to reach the 2030 objectives (BFP, 2022d). Regardless of the *Plan Fédéral de Développement Durable* (CIDD, 2021), out of Belgium's 82 indicators linked to SDGs, only 51 are projected to reach the objectives (BFP & ICN, 2023).

Given this context, two problems serve as core purpose to the present research. First and foremost, given the current literature Belgium's SDGs performances are set to be off target (Antwerp Management School et al., 2022; Government of Belgium, 2017; Orsini & Mazijn, 2017; Université Saint Louis & UCLouvain, 2018). Therefore, an analysis of why performances are not meeting the goals might enlighten stakeholders and push them towards well placed actions. Note that based on Belgium's SDG Barometer of 2022, the most relevant SDG according to organizations (state and non-state) are "Climate Action" (SDG 13). In that perspective, the performance analysis (reported in Chapter 5) will be looking at this SDG more in details.

Second, methodologically, the United Nations call for integrated and systemic methodologies to assess and plan SDG related policies (UNDP et al., 2016; United Nations, 2015; UNSDG, 2017), as authors realise the limits of the methodologies previously used and the problems they cause in the outcomes of the decision making process. Indeed, sector specific model-based studies provide detailed insights and solutions but the action proposed more often than not move the problems elsewhere (shifting the burden) or has unintended consequences on sectors that weren't taken into consideration (Bassi, 2015; Moallemi et al., 2022; Nguyen et al., 2023). In Belgium's context, the only study that provides a significant coverage of SDGs evaluates performances based on statistical extrapolation (BFP & ICN, 2023). In other words, it's assumed that future will be similar to the past, neglecting external factors and most importantly neglecting the chains of causes and effects that will lead to future development. Concerning long term scenario planning, various modelling techniques are used (Duerinck, 2012): accounting models, general equilibrium macro-economic models, econometric models, partial equilibrium models, optimization models, conceptual models, etc. The choice of methodology is justified by the field of application and the objective of the study. Model-based studies analyse fields such as energy (BFP, 2013; CLIMACT, 2021; ICEDD, 2018), population (BFP, 2022b), mobility (BFP, 2022a), economy (BFP, 2022c), etc. In light of this situation, there are still significant research gaps that need to be addressed to facilitate the implementation of the SDGs at the national level. These gaps can be categorised into two families (Gao & Bryan, 2017; Moyer & Bohl, 2019): the adaptation of global scenario frameworks to national contexts and the evaluation of SDG interconnections across various objectives and settings. Filling these gaps would greatly enhance the execution of the SDGs at a local level. Note that addressing the methodological issue will result in better tools of analysis to address the real problem of underperformance.

To tackle the methodological issue a literature review was conducted to ground the research in the current academic context and is reported in Chapter 3. The literature review tends to indicate a specific System Dynamics (SD) model which belongs to the family of approaches that evaluate SDG interconnections across various objects and settings: the integrated Sustainable Development Goals model (iSDG) (Allen et al., 2016; Collste, 2021; Liu et al., 2022; Pedercini et al., 2019, 2020). This model, developed at the *Millennium Institute* (NGO in Special Consultative Status with the Economic and Social Council of the United Nations), enables decision-makers and planners at all levels of government to comprehend how policies accomplish the SDGs, but also how they are interrelated. Providing a way to assess policies' potential effects before implementing them. The iSDG model covers all of the SDGs, and supports a better understanding of how the goals and targets are connected so that effective strategies can be developed to meet them. As a result, the thesis work benefited from the support of the Millennium Institute, who guided me in the process of calibrating and performing analysis with the iSDG model. More details about the model and why the model is suitable given the problem definition is explained in Chapter 2 and Chapter 3.

1.2 Research Objectives

The two purposes this thesis serves are:

(1) **adapt the iSDG model to Belgium** as a way to provide a first systemic, integrated, transparent, model for Belgium's sustainable development policy planning;

(2) **analyse the development of key indicators in a Business As Usual (BAU) scenario looking at the 2050 horizon** as a way to explore the interactions and interconnections between the SDGs in a qualitative and quantitative fashion.

Since the Millennium Institute has been developing the iSDG model for three decades and implemented it in over a dozen countries (Pedercini et al., 2020), this Master thesis aims at contributing to their work and academic literature by:

(a) Extending and broadening Millennium Institute's collection of iSDG adapted models to a high income country;
(b) Providing a sound foundation of structure for future policy structure that could be used in similar national planning contexts.

1.3 List of research questions

The model-based calibration and analysis will be framed by asking myself the following research questions: with regards to sustainable development, what can Belgium expect from a BAU scenario and how can we intervene to provoke encouraging results? To give a wider perspective and a better comprehension, I established the following sub-questions:

(a) What are the country specific data and structures that need to be implemented into the model to be able to represent Belgium's context?
(b) To what extent can the adapted iSDG model replicate the historical behaviour modes for all 17 Sustainable Development Goals and its key indicators?
(c) Where is Belgium heading given its current trajectories and underlying dynamics?

1.4 Research outline

For achieving the research objectives, I followed the System Dynamics modelling process (Sterman, 2000) by starting with the calibration of the model as a way to explore what sector within the iSDG framework needed revision in order to fit the Belgian context. Looking at the research objective (1), I distinguished three working phases. First, calibrating the structure and parameters across all sectors of the iSDG model with Belgium-specific data (Homer, 2012; Oliva, 2003; Sterman, 1984) which is reported in Chapter 3. Second, adding sectors and relationships to customise and address specific issues and interactions important to the country, outlined in Chapter 5. Third, conducting various validation tests (Barlas, 1996; Eker et al., 2019; Groesser & Schwaninger, 2012, 2012; Saysel & Barlas, 2006) discussed in Chapter 4. Each steps followed the rigorous and iterative nature of the SD modelling process (Sterman, 2000) to then address research objective (2) - conducting a BAU analysis, where results are in Chapter 5. Finally, based on the clear understanding and insights gained, I discuss in Chapter 6 quantitative and qualitative results that can serve as warnings or as encouragement for future policies.

Chapter 2: Model Description

2.1 Overview

As mentioned in the Introduction, this model-based thesis benefited from the collaboration with the Millennium Institute, resulting in the use of the iSDG model. Built upon the well-researched, time-tested, and proven Threshold 21 (T21) model, the iSDG model is the result of decades of system dynamics modelling work grounded in scientific literature (Barney, 2002). Covering all 17 SDGs with 78 quantitative indicators, the iSDG model is considered a large size model (over 48 000 equations) and is referred to one of the most relevant models for national development planning (Allen et al., 2016; Pedercini et al., 2020). Since 1993, the T21-iSDG model has been applied to over 40 countries from Denmark to Australia passing by China, Nigeria, Fiji, and the United States (Millennium Institute, 2023c). It helped policy makers develop national plans regarding: green economy, sustainable agriculture, renewable energy transitions, and industrial reform (Pedercini et al., 2020).

Given the transparency aspect of the method, the software tool used (Stella Architect ® v3.3.0 from isee systems inc.), the user-friendly interface and the potential participative approach of model development, the iSDG model allows policy makers to set the agenda and discuss in a pragmatic fashion the problems at hand. Following which, it allows stakeholders to formulate and test policies through scenario planning. Starting with a typical "Business As Usual" scenario, scenarios like "National Development Plan" Scenario and any other policy scenario can be compared with one another across all SDGs. Indeed, the iSDG model allows policy makers to conduct cross sector impact analysis for testing policies and its impact within and outside the sector concerned by the policy through propagation and feedback loops. Moreover, the iSDG model enables the user to simulate multiple policies individually and in aggregate, resulting in a better understanding of possible synergies and in quantitative assessment of them (Pedercini et al., 2019). Finally, the iSDG model can assess the performance of a country working towards a certain goal whilst taking into account the dynamic causal changes (Pedercini et al., 2020).

In the model, the 17 SDGs are categorised in 30 sectors (also referred to modules) displayed within the three dimensions of sustainable development (see Figure 1): environmental (outer ring, in green), social (second ring, in red) and economic (inner ring, in blue). Note that each sector can be seen as a separate model, where input comes from other modules or from exogenous data. The interconnection displayed through blue arrows in Figure 1 represents the causal relationship that takes place between the sectors, forming a complex web of interactions. Behind this complexity, lies modelling assumptions that represent one of the many ways reality may be perceived. To give an overview of these assumptions, I have decided to group them through the three dimensions previously mentioned. For a sector detailed description, a full documentation of the model is published online (Millennium Institute, 2023b).

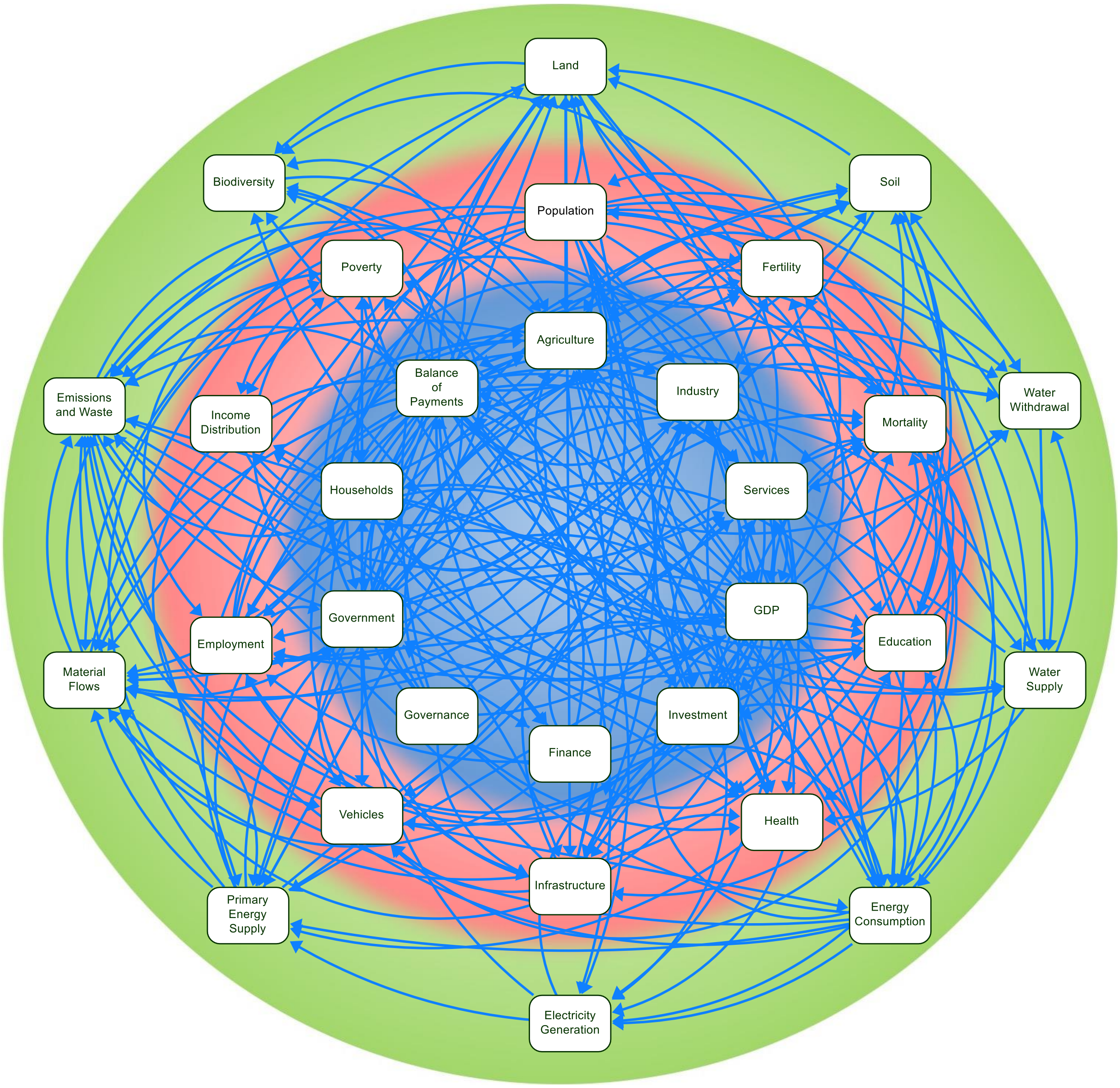

Figure 1 – High-level structure diagram of the iSDG model

2.1.1 Economic sectors

The production sectors in the economy, namely Agriculture, Industry and Services, are modelled using the Cobb-Douglas production function, with inputs: labour, capital, and endogenously computed total factor productivity. Note that total factor productivity is affected by variables coming from other sectors such as Education, Health, Inflation, Infrastructure, etc. On the other hand, capital is defined based on the capital formation and consumption (or depreciation). The first is impacted by investment which follows a return on investment logic expressed in the Investment module. The second is impacted by the average life of capital and the damages caused by natural disaster. All three production sectors are then accounted in the overarching GDP sector, which accounts for the aggregated indicators of production such as gross domestic product, gross national income, sector specific deflators, etc. Concerning the Government module, it's split up into two sections: revenues and expenditures.

Revenues are generated based on economic activity (taxes on incomes, taxes on goods and services, taxes on international trade, etc), which are then allocated across different expenditures categories through historical data for past values and user input parameters for future values. Note that the Governance module consists of six indicators that affect the productivity and effectiveness of public expenditure. Revenue and expenditure meet to define the operating balance which impacts the indicators regrouped in the Finance module such as public domestic debt and public foreign debt. Based on the production values and the government accounts, the model takes into account standard budget categories and macroeconomic balances in the Balance of Payments module in order to track trade and financial transactions. Finally, the Household module tracks household income, including subsidies, transfers, and remittances, and their impact on private saving and consumption.

2.1.2 Social sectors

The social modules encompass various aspects such as population dynamics, health and education, basic infrastructure including roads and rails, employment, poverty levels, and income distribution. The Population module, categorised through gender and age, benefits from the results of the Mortality and Fertility modules and incorporates an exogenous migration component. The Mortality module accounts for life expectancy but also mortality rates by cause and age, which are affected by elements such as health, education, income, emissions, road mortality, natural disasters. On the other hand, the Fertility module is impacted by contraceptive prevalence, and other socio-economic variables such as income and education.

Moreover, education variables regrouped in the Education module categorise population through six education levels, given school expenditure and endogenously computed dropout rates. Concerning infrastructural components, the Infrastructure module tracks the evolution of roads and railways, given the budget necessary to maintain them and the expenditure allocated to expand these networks. Moreover, the model takes into account the impact of natural disasters on infrastructure and gives the possibility to test infrastructure adaptation policies. With regards to vehicles, the Vehicles sector disaggregates the vehicles stock in four categories, through the passenger and commercial dimensions, and through the combustion and electrical dimensions. Furthermore, it keeps track of the age of the vehicles stock and the fuel efficiency given their age allowing to measure the trends in the different fleets but also in the total fuel consumption and emissions.

At the frontier of economic sectors, the Employment module factors the hiring in each production category (agriculture, industry and services), given the availability constraints and the working age population. Additionally, it computes the gender gap in employment by taking into account the gender difference already present in education. Finally, production is distributed in the Income Distribution by accommodating for: the share attributed to capital remuneration, the share attributed to salaries and wages, the subsidies, and the tax distribution. Resulting in poverty levels that are reported in the Poverty module.

Overall, the Social module takes into account the interactions between income, healthcare, nutrition, and average years of schooling, and how they impact fertility and life expectancy, which ultimately determines population growth. Population growth, in turn, affects the labour force, education levels, and capital accumulation, thereby shaping employment opportunities. Furthermore, education, employment, and savings levels have an impact on income distribution and poverty levels. Education and healthcare, along with other factors, impact labour productivity and life expectancy. Similarly, basic infrastructure and vehicles affect productivity, but they also increase the demand for fossil fuels and emissions, thus impacting health levels.

2.1.3 Environmental sectors

Environmental sectors cover energy, climate and natural resource dimensions. The energy sectors namely: Electricity Generation, Primary Energy Supply and Energy Consumption operate hand in hand to compute, for each energy source, the energy produced and consumed, whilst accounting for energy transformation losses, imports and exports, relative energy prices and production costs. All of which directly impact the Emission and Waste sector, as the energy consumed is translated into the different emissions (PM 2.5 and GHGs). However, energy related emissions are not the only emissions accounted for, as agricultural, industrial processing, waste management and land use change are also all endogenously calculated. In addition to emissions, the model computes waste generation based on national income. Moreover, iSDG Belgium also enables to track the material flow repercussion of the economy in the Material Flow sector. In other words, the extraction and consumption of renewable (biomass) and non-renewable (fossil fuels and minerals) resources evolve based on agricultural production, industrial production, energy consumption, private consumption, public consumption and capital formation. Allowing the model to estimate the material footprint of Belgium's economy. For a wider coverage of resource use, the model also accounts in the Biodiversity sector for fishing stocks and the availability of fish which is affected endogenously by the rate of fishing production.

Concerning pure environmental sectors, the Land sector accounts for changes in agricultural, forest, settlement and other lands based on the demand for agricultural and forest production, but also in the changes in population. Furthermore, depending of policy choices, it enables the model user to protect areas of forest land or start a reforestation program. Linked to the Land sector, the Soil sector follows the dynamic of soil nutrition through nutrient uptake and losses which are affected by agricultural production, precipitation and land use. Moreover, the model records for fertilizer consumption, nutrient deposition and sedimentation, nutrient from manure application, crops biological fixation whilst factoring for fertilizer costs and subsidies. Finally, the model details the dynamics of water supply and demand in the Water Supply and Water Withdrawal sectors.

To conclude the Environmental sectors interact with one another and with sectors of other dimensions. For example, resource stocks (such as fish stocks and forest cover), the quality of soil impacts other modules, such as agricultural productivity, nutrition and biodiversity which then feedback into the environmental sectors. Likewise, a number of aspects, including productivity, access to electricity, access to water and sanitation facilities that affect education, health levels, and emissions are impacted by the demand and supply of fossil fuels, energy, and water.

2.2 Feedback Processes

The objective of this section is to highlight the main feedback processes that are included in the iSDG model. The list and representation of these processes are limited, simplified and only represent a small amount of the entire feedback loops. To do so Figure 2 highlights, in a generic fashion, the feedback processes that are taken into consideration in the model's structure.

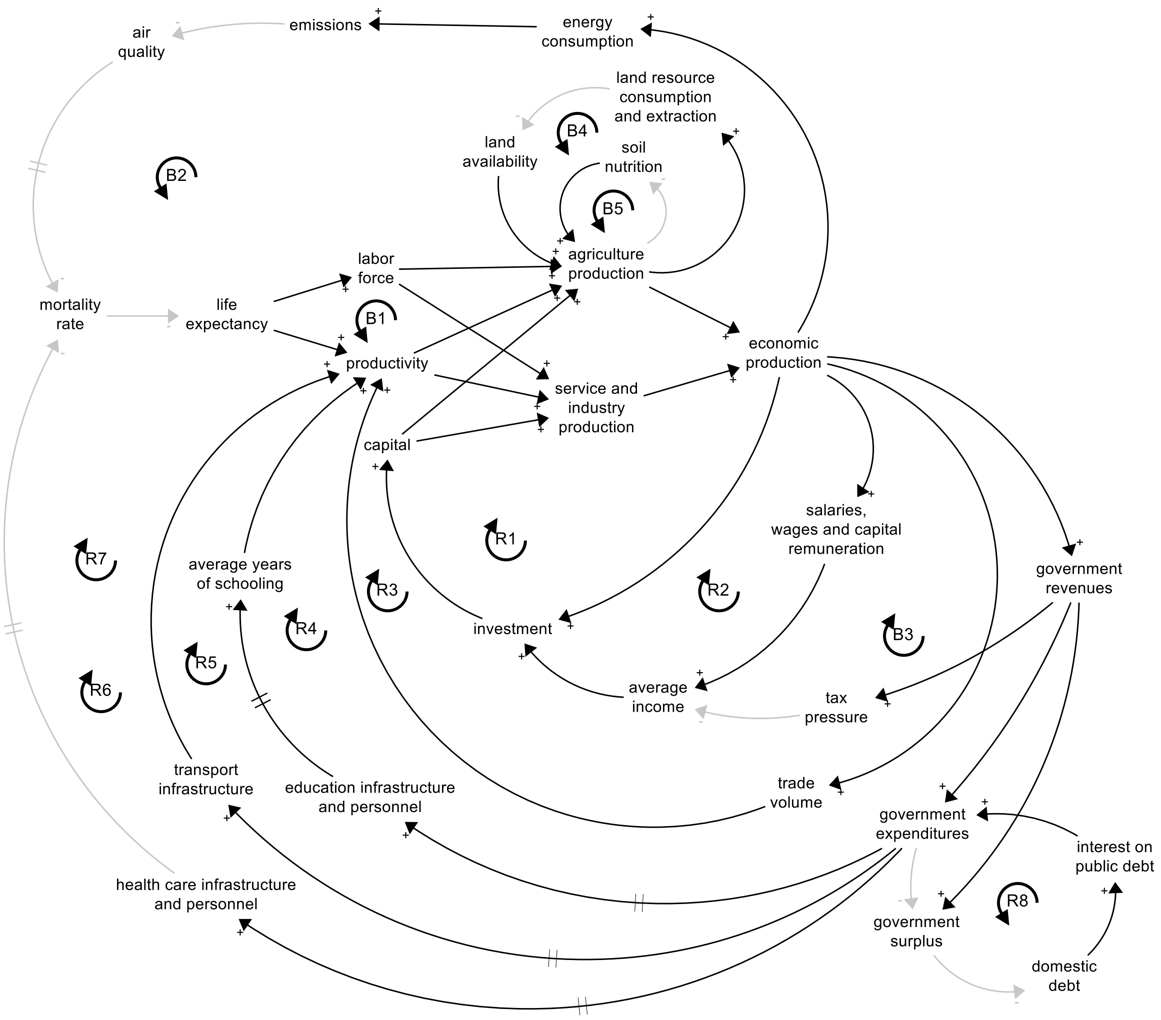

Figure 2 – Simplified Dynamic Hypothesis of iSDG's major feedback loops

Market Growth Loop (R1). The more is invested in capital, the more the economy will be able to produce. Following a return-on-investment logic, the more we produce, the more we will want to reinvest in capital and further produce. If this loop is considered isolated from the others or dominant in the system, it would lead to exponential growth.

Emission Backlash Loop (B1, B2). The more the economy produces, the higher the energy consumption. Given the current energy mix, if energy consumption increases, then greenhouse gas and fine particles increase causing the quality of the air to decrease. However, air quality has an impact on human health. As air quality decreases, respiratory diseases tend to increase, causing mortality rates to increase. If mortality rate increases, then life expectancy decreases which leads to a decrease in economic productivity and in labour force. Therefore, the initial increase in economic production was balanced out by its emissions effect. If this loop was dominant or isolated from the rest of the system this would lead economic activity to experience a significant drop.

Resource Limitation Loops (B4, B5). The market growth loop described is balanced out by a series of natural processes that limit economic production to grow indefinitely. At national level, one of these natural feedback processes lies in the agricultural production. Conventional agricultural practices have a tendency to use chemical fertilizers and pesticides which lead to a decline in the soil's health. Therefore, an increase in agricultural production leads to a decrease in soil nutrition. In turn, the lower the soil nutrition the lower the agricultural production. Moreover, the more is produced in the agricultural sector, the higher the consumption and extraction of land resources. This increase leads to a higher demand for land but given the limited amount of domestic land available for agriculture, this leads to a decrease in land availability. Finally, the less land we have available the less we are capable of producing. In both cases (soil health and land availability), an increase in agricultural production leads to its downfall. In other words, we have a balancing loop.

Note that there are other natural processes that counter act the exponential growth of the market which takes place at the global level. For example, global emissions that result from economic production led to higher global temperatures. This increase in temperature affects the frequency and the scale of natural disasters. The more natural disasters, the more damages on economic capital, leading to a decrease in economic production. However, these feedback processes are not explicitly taken into consideration as domestic emissions have an extremely small impact on global processes such as climate change. Nevertheless, instead of having these feedback processes endogenously defined, temperature change is exogenously driven so that the impact on economic capital is taken into consideration. The same idea is applied to the model structure for frequency of natural disaster and yearly precipitations.

Wealth Distribution Loops (R2). The higher the economic production, the higher the salaries and capital remuneration, leading to a higher average income. Through taxes, subsidies and transfers, this wealth is distributed. The choice individuals have is then to consume or to save. Based on their propensity to save, the wealth accumulated leads to investment, which further increases the economic production.

Trading Loop (R3). Economic production isn't just affected by capital, it's also affected by the productivity of the agents that take part in the economy. The productivity is, among other factors affected by the economy's openness to the outside world. The higher the trade volume, the higher the productivity. The higher the productivity, the higher the production. The higher the production, the higher the trade volume. An increase at the beginning lead to an increase at the end of the loop. In other words, this loop is a reinforcing loop capable of producing exponential growth.

Governmental Productivity Loops (R4, R5, R6). Based on economic production, the government captures some of the wealth, through taxes on goods and services, defined as revenue. Following which it decides based on the political agenda to spend this revenue in its different functions. The three traditional functions the government is meant to fulfil is covering expenditure related to education, healthcare and infrastructure. These later affect the productivity directly for infrastructure, through life expectancy for health, and through average years of schooling for education. In other words, an increase in these expenditure functions, leads to an increase in productivity. Leading to higher economic production, which, in turn leads to higher revenue and the capacity to have higher governmental spending in the future. Note that there are implementation delays between the time expenditure takes place and when productivity increases. Indeed, it takes time to build roads and for the economy to adapt and use it in its interest.

Governmental Labour Force Loop (R7). The healthcare expenditure has its first impact on productivity as described through R6, but this later has also an impact on labour force. Indeed, if the healthcare system is performing efficiently, it will lead to a healthier population and lower mortality rates. In turn, this leads to a bigger workforce and therefore a higher economic production. Higher economic production leads to higher revenue and the possibility to increase expenditure.

Debt Traps Loop (R8). As government increases its spending, if they are higher than the governmental revenues then the surplus will be negative causing the debt to increase. As the debt increases, the interest on it will also increase causing the government to spend its revenue on interest and further worsening the deficit leading to higher debt. In other words, if revenues don't increase as expenditure does or if expenditures don't align with revenues, then this loop leads to exponential growth of the public debt.

2.3 Model Limitations

Even though the System Dynamics methodology and the iSDG model display unique qualities as mentioned in Chapter 2 and Chapter 3, they also have intrinsic limitations. Because of the breadth of scope of the iSDG model, it loses in sector specific details and accuracy. Indeed, it won't be capable of simulating point by point forecasts, nor will it be able to provide as many details as sector dedicated models. Furthermore, uncertainties regarding future values are built as modeller assumptions. In that regard, the boundaries of the model limit the analysis that can be conducted. Indeed among exogenous variables there is: energy prices, fertilizer prices, commodity prices, electricity capacity load factor, electricity capacity costs, energy transformation and losses, emissions per tonne of production, monetary consumption to material consumption equivalents, national temperature change, crop calorific content, imports and exports, and net migration rate. To deal with the uncertainties of these exogenous variables, System Dynamics relies on validation techniques such as sensitivity analyses to produce a wider range of plausible modeling results and to identify the parameters or model elements that have the biggest impacts on the results (see Chapter 4).

With regard to the adapted iSDG Belgium model, the calibration and adaptation process has shown one major limits: Belgium's SDG coverage. The time span of the project imposed that the priority be put on adapting the existing structure to Belgium's context, however the existing structure is defined based on the very broad framework of the 2030 Agenda and on the Millennium Institute's experience which has majorly been with developing countries. Therefore, the main indicators used in the list of SDGs are limited for Belgium's specific needs and to some extent are not relevant (i.e. proportion of population below international poverty line, proportion of population with access to electricity, prevalence of undernourishment, etc.). In that regard more work could be done to integrate some other indicators such as the ones mentioned in the *Conference of European Statisticians recommendations on Measuring Sustainable Development* (UNECE, 2014) or the collaboratives studies made by the *Bureau Federal du Plan* and the *Institut des Comptes Nationaux* (BFP & ICN, 2023).

Chapter 3: Methods

This chapter's objective is, first, to give a detailed explanation on why System Dynamics can be useful for both the problem of underperformance and to answer the call for integrated and systemic methodologies for SDG performance analysis or scenario planning. Secondly, the objective is to describe methodology is used for each of the research objectives.

3.1 Research Methodology

As the world is getting more and more complex (Leach et al., 2010), the SDGs and their underlying indicators give a direction, but don't take away from the complexity of the development pathway that needs to be achieved. By definition, sustainable development is at the crossroads of three arenas: social, economic and environmental (World Commission on Environment and Development, 1987). It's also a process that takes time, where major delays are involved, where changes occur in a non-linear manner through a continuous process of self-correction, where resources accumulation contributes to the rate of production but also the other way round (Pedercini, 2009). Given this complex policy space, literature calls for evidence based methodology that can provide both quantitative and qualitative knowledge (OECD, 2020). Moreover, in the context of public policy, system thinking is increasingly recognised and implemented (Nguyen et al., 2023) as the need of integrating the different dimensions has become more and more critical (Collste et al., 2017; Diemer et al., 2019; Giupponi et al., 2022). In other words, public policy dealing with sustainable development are in need of a methodology capable of representing the complexity of reality in an integrated fashion, including non-linearity, accumulations, delays, and feedback processes (Breuer et al., 2019).

Integrated Systems Models (ISM) provides multisector simulation tools capable of designing and testing policies in this complex environment (Elsawah et al., 2017; Pedercini et al., 2020). Within this family of models, the System Dynamics (SD) methodology has been considered as leading the way with regards to sustainability (Allen et al., 2016; Boulanger & Bréchet, 2005; Kelly (Letcher) et al., 2013; Malbon & Parkhurst, 2022). Examples range from best seller report *Limits to Growth* (Meadows & Club of Rome, 1972) to a rich academic literature that tackles energy (Selvakkumaran & Ahlgren, 2020), transport (Fontoura & Ribeiro, 2021), climate (Kapmeier et al., 2021; Randers et al., 2019), health (Darabi & Hosseinichimeh, 2020), poverty (Liu et al., 2022), agriculture and natural resources management (Turner et al., 2016), etc.

Conceptualised in the late 50's and founded in the early 60's at the Massachusetts Institute of Technology by Jay Forrester (Forrester, 1973; Richardson, 2011), SD is three things at once: a systemic problem thinking process, a set of tools and a modelling method (Sterman, 2000). Closely linked to, if not embedded in, System Thinking, SD is part of the complexity science school of thoughts (Dangerfield, 2020; de Rosnay, 1975; Duran, 2017; D. H. Meadows & Wright, 2009).

SD seeks to move away from the cartesian way of thinking by breaking the silos between elements and considering them in a holistic fashion. SD remains a pragmatic and problem-oriented methodology. Indeed, elements are considered as part of a whole where they interact with one another but the boundaries of the system defined are set by the problem SD is used for. As a modelling approach, it grasps intertwined relationships of components that are usually confused in our minds, and "put them on paper" in an intuitive, iterative, explorative process resulting in a model - also referred to as a virtual world (Sterman, 2018) or an abstract representation of reality. To shape that reality, SD makes relationships explicit conceptually (through diagrams and graphs) and mathematically (through differential equations), bridging qualitative and quantitative analysis, making mathematically complex results understandable and usable to a broad range of actors. It is an attempt at moving away from the so-called "black box" modelling approached and reaching into "glass boxes" for full transparency (Rouwette et al., 2004; Sterman, 1992), inviting discussion about the underlying causal structure of the system, further enabling participative projects with Group Model Building (Hovmand, 2014; Vennix, 1996). Where SD differs from other operational methods with regards to complex dynamic problems is in its combined use of computer simulation, quantitative and qualitative data, feedback loops, and most importantly visualisation tools for rendering our mental models (Richmond, 2001). SD explores the causal relationships of different elements to alleviate the uncertainty, grasp the reason of problematic behaviour through analysis to better guide the changes we would like to see in the system (Mutingi et al., 2017).

3.2 First Objective - Adapt the iSDG model

To adapt the iSDG model there are two major phases to distinguish: data collection and model calibration. Note that these two phases were performed in that order but in an iterative fashion. In other words, first, a significant amount of data was collected and imported in the model, then calibration started but that process highlighted data gaps or errors, therefore I had to go back to the data file and re-collect or adjust the data collected initially.

3.2.1 Data collection and analysis

The data collection process' objective is to assemble information concerning the evolution of Belgium's SDG indicators and elements that cause these indicators to change over time. In light of the goal of operationalising policy insights, information is more powerful if it combines quantitative and qualitative natures. Data was gathered from both global and local data sources (i.e. *Table 1* gives deeper understanding of these different sources). By global data source, I mean data bases that are the result of political agreements which lead to a compilation of national datasets that obey the same statistical framework (i.e. Eurostat, World Development Indicators, International Monetary Fund data, etc). By local sources, I mean specific data bases of Belgium that have their own statistical framework (i.e. National Bank of Belgium, Statbel, etc). Due to the timeline of the project, this later had to benefit from an automated data collection process defined by the Millennium Institute. This automated data collection process collects a wide range of time series data from global data sources through programming language scripts. This results in a first data set for Belgium. However, manual data collection is then conducted to fill in the gaps with local data when global data did not exist for particular metrics, or inaccurate. Where the available data is insufficient, experts from the *Bureau Fédéral du Plan* (BFP) were closely involved in the process to guide the search in the right direction. Furthermore, to fill the remaining gaps, assumptions on the behaviour of the time series were developed. Occasionally, because of measurement or reporting changes, historical data were modified to maintain consistency. Moreover, the historical datasets occasionally lacked internal consistency, despite best attempts to replicate historical data. For example, employment is decomposed in its different categories (agriculture, industry and services) but it doesn't add up to the sum total. This is mainly because several data sources were utilised to cover a wide time span. As a result, trade-offs and compromise were established to guarantee that the model accurately represents Belgium's context. For example, if the data source for total employment is preferred to the source for its decomposition, we proceed as follow: (1) generate the share of each employment category by generating an unreliable total employment time series, (2) generate the decomposition based on the shares generated and the trust worthy figures of total employment, (3) replace the decomposition data by the generated one. More information on the data sources of each module as well as the main presumptions around the data can be found in the supplementary material (i.e. iSDG_Belgium.xlsx file).

On a research strategy stand point, the objective is to gather quantitative information on various time series and parameter values that are necessary in the different phases of the model development (building, testing, validating, comparing). The idea is to develop a model-tailored database for iSDG Belgium. Based on the structure of the model and the modelling process, the main data needed are time series. Time series that are used in four different ways: historical data (to compare simulation runs), temporarily exogenous data (to perform calibration), parameters (for the simulation's initial values), and permanently exogenous data (serving as input to the model).

We distinguish three phases in the data collection process where phases 2 and 3 are repeated iteratively (see Annexe 1 for details of each phase):

Phase 1: Automated time series collection through first set of databases

Phase 2: Manual time series collection through second set of databases

Phase 3: Manual estimation, calculation, adjustment of time series collection

Table 1 – Summary of Data Sources

Source categories	Sources	Sector Contribution	Collection method	Processing method
Global Sources	World Bank's World Development Indicator (WDI)	All sectors	Automated collection process of the Millennium Institute	Automated processing process specific to the Millennium Institute
	Food and Agriculture Organization (FAO)	Agriculture, Emissions and Waste, Land, Material Consumption, Soil, Water supply, Water Withdrawal		
	International Energy Agency (IEA)	Electricity Generation, Energy Consumption, Material Consumption, Primary Energy Supply, Vehicle		
	International Monetary Fund (IMF)	Employment, Finance, Government		
	World Health Organization (WHO)	Mortality		
	International Labour Organization (ILO)	Employment		
Local Sources	European Statistics (Eurostat)	Agriculture, Employment, GDP, Health, Land, Services,	(a) Identifying the needed time series (b) Search through database for suitable data (word search or category search) (c) Delineate potential useful series (d) Conduct compatibility check (definition and units) (e) Export data	(a) Upload exported data in new sheet (b) Define the nature of the exported data. (c) Execute unit conversion (if needed) (d) Undertake calculation, estimation, adjustment work (if needed) (e) Transfer data to 'Data' sheet
	National Bank of Belgium (NBB)	Agriculture, Employment, Finance, GDP, Government, Investment		
	Bureau Fédéral du Plan (BFP)	Health		
	STATBEL	Governance, Poverty, Vehicle		

3.2.2 Model calibration

The model calibration process begins when the data gathering phase is complete. In this stage, suitable parameter inputs are sought in order to modify the model to the nation's unique setting. After the model has been parameterized, it may be used to simulate the past behaviour and develop future scenarios. Given the size of the model, calibrating the entire model all at once would have conflicting consequences across sectors, besides the technical difficulties regarding large optimization spaces, therefore the main method used for calibration is partial model testing. Partial Model Testing (Homer,

2012) ensures that the structure properly reproduces the behaviour to prevent over-fitting (behaviour reproduction for the wrong reasons). This process can be broken down into four steps: (1) isolate each partial-model, (2) estimate parameters, (3) integrate partial-models, and (4) assess and revise (Millennium Institute, 2023a).

In the first step, sectors are divided into sub-models and calibrated without interconnections following calibration best practices (Oliva, 2003). In other words, a payoff variable is identified (which will be the key indicator compared to historical data), and a partial-model structure is created (structure which only includes the structure that directly impacts the payoff variable). For example, to calibrate the mortality sector, the payoff variable selected is life expectancy and the partial-model structure created includes all the main causes of its development (road injury mortality, natural disasters, health care expenditure, etc.) some of which see their equation overwritten by historical data (temporarily exogenous input variables).

Concerning step two, optimization algorithms are used to estimate the impact of each parameter on the relationships between variables, by searching within predefined thresholds (see Annexes for parameter values and thresholds). The parameterization was supported by reference parameter ranges based on expert literature and decades of empirical experience. The goal of the optimization search is to minimize the error between the simulation and historical data. When the optimization space is less complex, the Powell algorithm is used for efficiency. However, as Powell is a local search technique, it may not identify all optima or global optima. For more complex cases, Differential Evolution is used to explore parameters more thoroughly. This process is done iteratively for each partial-model in the iSDG model, resulting in the model being broken down into hundreds of smaller models and calibrated individually.

For step three, the step by step process consists in endogenizing the variables that were kept exogenous until there (equations were replaced by historical data). Each exogenous variable is endogenized one by one. In other words, we let the equation defines its behaviour instead of replacing it by data. For each variable, the behaviour of all key performance indicator undergoes verification to see if some error is introduced. In such a case, we asses where the error comes from and undergo revision through a reiteration of the calibration process. The process of revision is done using both the variable time-series data as well as by calculating statistics to indicate model fit (see Chapter 4 for more details about behaviour reproduction analysis). Table 7 in Annexes summarises all the parameters used in the process, reports the value taken after optimization and gives the range in which the algorithm searched for optima.

Overall, with the help of this method, we may intuitively comprehend how parameters affect partial models but we can also test the assumptions regarding model's structure. Furthermore, this process highlighted the fact that some modules required modifications or additions to the model structure to better reflect Belgium's situation, for example for the Material Flow, and Emission and Waste sectors (see Chapter 5 for details regarding these later changes). Note that the calibration was part of the structure oriented behaviour tests conducted in the validation procedures (see Chapter 4 for details about other validation tests).

3.3 Second Objective - Analysis of BAU

For the analysis of the Business As Usual scenario, the first step was to expand the time horizon used for calibration (year 2020) to the year 2050. The choice of time horizon is justified based on the fact that most prospective studies made at national level go beyond the previously used 2030 horizon. Therefore, as a way to address the research objective of insight operationalisation, the choice of 2050 was withheld. This change in time horizon created the need to make assumptions on exogenous variables. For a full detail of the assumption made see the data file 'iSDG_Belgium.xslx' in the supplementary material. In order to give an overview of these assumptions see Table 2. Note that in most cases if the variable is not mentioned in the table that follows then the assumption is that the variable was set as constant for the 2020 to 2050 period and equal to its 2020 value.

Once the assumption regarding exogenous variables was set and the model was capable of running simulations until 2050, the key performance indicators were compared to other simulation studies in order to verify the plausibility of the projections. Following this process, I follow the best practices of System Dynamics (Martinez-Moyano & Richardson, 2013) by using simplified causal diagrams to effectively illustrate the stories at hand, describing unconventional behaviour in order to provide meaningful insights into the actual system, creating concise models representation that concentrate on specific issues and intriguing patterns of behaviour, using the underlying causal structure and feedback loops to explain the behaviour observed, chopping up the time horizon to detail the development over each period of time, explaining stock development through its flows (Sterman, 2000). All of which will be reported following the guidelines of Rahmandada and Sterman (2012).

Table 2 – Major Assumptions of the BAU scenario

Sector	Variable	Assumption
Government	Expenditure by main category	Expenditures by main category are set as constant for the 2020 to 2050 period and are equal to the 2020 share of each category in GDP
	Taxes	Taxes and Grants are set as constant for the 2020 to 2050 period and are equal to their 2020 share in GDP
	Grants	
GDP	Relative deflator growth rate	Relative deflator rate is set as constant for the 2020 to 2050 period and equal to the average of the last five years of the historical period for each economic sector
Agriculture	Value added per tonne	Value added per tonne variables are set as constant for the 2020 to 2050 period and are equal to their 2020 values
Population	Net migration rate per thousand people	All variables are set equal to the United Nations Population Division's median projections
Fertility	Age specific fertility distribution	
	Total fertility rate	
	Births by gender	
Mortality	Mortality rates by age and gender	
Electricity Generation	Electricity capacity load factor	For non-renewable sources, the capacity source factors are set as constant for the 2020 to 2050 period and equal to their 2020 value. For renewable sources, the capacity load factors are set as linearly growing towards the International Energy Agency projections
	Electricity capacity cost	Electricity capacity cost variables are set as linearly growing towards the International Energy Agency projections
Material Flow	Net material trade fraction	Set as constant for the 2020 to 2050 period and are equal to their 2020 values
	Raw Material Equivalent of consumption or capital formation	

Chapter 4: Validation

Barlas and Carpenter (1990, p. 157) argue that *“models are not true or false but lie on a continuum of usefulness. Model validation is a gradual process of building confidence in the usefulness of a model”*. To build such confidence and following the guidelines of Barlas (1996) and Sterman (2000), I performed three different validation tests: direct structure tests, structure oriented behaviour tests and behaviour reproduction tests. All of which were conducted iteratively throughout the modelling process and address **objective (1)** of this thesis (adapt the iSDG model to Belgium).

4.1 Direct Structure tests

The purpose of direct structure tests is to ensure that the real system’s structure is accurately represented (Senge & Forrester, 1980). These family of tests include: empirical tests (structure and parameter), theoretical tests (structure, parameter, extreme-condition, dimensional consistency, boundary adequacy), implementation test. Empirically and as reported in Chapter 3, the model structure is constructed from a vast quantity of literature based evidence including peer-reviewed sources (Millennium Institute, 2023b). Concerning parameters, their validity come from actual data where data availability made it possible and calibration otherwise. The calibration process involves partial calibration cycles where individual sector modules are adjusted (Homer, 2012) as described in Chapter 2. For direct extreme-condition tests, the model's parameters were changed to have incredibly low or incredibly high values, and the model software was used to determine whether any computational mistakes would result. These tests turned up no mistakes, therefore it can be said that the model's structure is sufficiently resistant to adverse circumstances.

Using the “check units” feature of the modelling program, dimensional consistency tests were run. As there were no reported unit faults for this model, the overall dimensional consistency may be confirmed. Moreover, the modelling team of the Millennium Institute and myself made sure that the units have real world counterparts to ensure that no variables were added to force the model to work. Concerning boundary adequacy, the adequacy can only be judged based on the purpose of the study. This later is defined in Chapter 1 as grasping the interrelations that occur in the dynamic context of Belgium’s SDGs to understand the growing trends in a Business As Usual scenario for the main SDG indicators. Therefore, given the fact that the model’s structure encompasses all SDGs and details quantitively the feedback processes between them, the boundary adequacy tests passes. Note that the boundaries can and should be redefined if the purpose of the study leads into a certain direction or asks for a more detail rich analysis. Finally, on an implementation stand point, the model went through formal inspections, reviews, walkthroughs, and semantic analysis. Indeed, since the model benefitted from the Millennium Institute experience and continuous modelling efforts, the structure has been tested and revised by government agencies' experts (PAGE, 2017; UNEP, 2011) and academics (Allen et al., 2019; Bassi, 2011; Collste et al., 2017; Kopainsky et al., 2010; Pedercini, Kleemann, et al., 2018; Pedercini, Zuellich, et al., 2018) around the world for over two decades.

4.2 Structure Oriented Behaviour tests

The purpose of structure oriented behaviour tests is to keep on testing structure through simulation behaviour. As mentioned in Chapter 2, calibration and the partial model testing conducted within this later process serve as a first round of tests that enabled to identify needed structure changes which were reported in Chapter 3. A second round of tests could be conducted: behaviour sensitivity tests. Due to time constraints, scale of model and prioritisation of behaviour reproduction tests, the behaviour sensitivity tests were not conducted. However, I still found it necessary to give a brief explanation of what these tests would look like if a later analysis found more purpose in these tests. Behaviour sensitivity tests demonstrate how responsive the model's behaviour is to regular changes in the parameter values (Schwaninger & Groesser, 2016). Sensitivity analysis is utilized to complement and support the model calibration process, as well as to evaluate model assumptions (Ford, 2009; Ford & Flynn, 2005). This analysis provides valuable information on how modifications in uncertain parameter inputs relate to changes in performance metrics. For intricate and expansive system dynamics models, like the iSDG model, Sterman (2000) recommends to concentrate on parameters and relationships that are both highly uncertain and expected to exert a significant impact. To provide a wider understanding of the model's sensitivity, variables across all three dimensions (economic, social and environmental) should be integrated. For example, domestic inflation, net migration rate, or national temperature change among other parameters could be tested.

4.3 Behaviour Reproduction tests

The purpose of behaviour reproduction tests is to make sure that the model is capable of replicating the system behaviour for the right reasons. Moreover, "goodness-of-fit" is defined relative to the model's purpose (Forrester, 1973). Note that System Dynamics models are in most situations not designed to be forecasting models, therefore the behaviour reproduction tests are limited to replicating behaviour modes whilst fitting in the right numerical scale. In other words, the objective of model calibration is to precisely represent the historical data's medium to long-term trends, with lower focus on short-term cycles. As a result and to evaluate the goodness of fit, the model uses the following metrics (Millennium Institute, 2023a): R-squared (R^2), Root Mean Square Percent Error (RMSPE), and Theil Inequality Statistics: Bias (UM), Variation (US), and Co-variation (UC). A comparison of the correlation between the simulated and historical series is made using R^2, or the coefficient of determination. It is measured between 0 and 1 (1 representing a perfect fit), and explains how much of the change in the dependent variable (historical) is made by the independent variable (simulation). This later is improved by the

RMSPE which displays the percentage of error between historical and simulated data (the lower the RMSPE the better). Furthermore, UM, US and UC deconstruct the error by identifying the causes of mistake enabling us to identify. The UM measures the average difference between simulation and history. A large error with a majority of it being in bias could indicate a systematic error in the model. The US measures the difference in variation around the mean of the time series and how well the model tracks cycles in the data. Meanwhile, the UC measures how well the simulation matches trends point-by-point. If the total error is low and the observed error is mainly in US and UC, then the model effectively tracks long-term trends, assuming a low UM.

Table 3 displays aggregate model summary statistics. By condensing the common goodness-of-fit statistics, this gives a brief summary of the calibration's overall outcome. Two additional significant metrics are added to statistics described previously: the population (N) and the Data Coverage. The population parameter (in columns) denotes the total number variable used in the calibration, whilst the population parameter (in rows, N) denotes the number of historical data points per variable that is included in the calibration (maximum 21 given the time period of 21 years). The second, Data Coverage, represents the proportion of data points covered during the calibration period, in this case 2000–2020.

Overall, 204 variables were used to calibrate the model. Because some statistics cannot be generated for variables that have insufficient data points, the total number of variables (the population column) used for each statistics varies. The historical data at the time of the model calibration covers 97% percent of these 204 variables. As can be seen in Table 3 and Figure 3, tFigure 3 – Model Summary Statistics Distributionshe model performs well generally in terms of goodness-of-fit statistics. The simulation and historical time series exhibit a significant link, as indicated by the mean R^2 (0.73). The model's mean RMSPE is of 6% with a standard deviation of 10% indicating a low average error value. RMSPE falls below 14% for most variables, with just a few outliers skewing the distribution.

When determining the cause of the mistake represented in the RMSPE, we see that the bias error has a mean value of 0.23. In terms of error resulting from variation, there is often little error resulting from variation, with few variables' error rising beyond 0.17. Last but not least, the distribution of UC demonstrates that co-variation (0.62) is mostly to blame for the mistake that occurs in the model. The average inaccuracy is generally within acceptable bounds. This demonstrates the non-systematic nature of the model's inaccuracy and highlights the close relationship between the model's output and the medium- to long-term patterns found in historical data sets.

Table 3 – Aggregated Model Summary Statistics

	Population	Mean	Median	Minimum	Maximum	Standard Deviation
N	204	20.40	1.00	9	21	1.73
Data Coverage	204	0.97	0.89	0.43	1.00	0.08
R^2	198	0.73	0.03	0	1.00	0.31
RMSPE	203	0.06	0.14	0	0.99	0.10
Um	202	0.23	0.08	0	0.98	0.25
Us	202	0.17	0.65	0	0.91	0.20
Uc	197	0.62	1.00	0	1.00	0.27

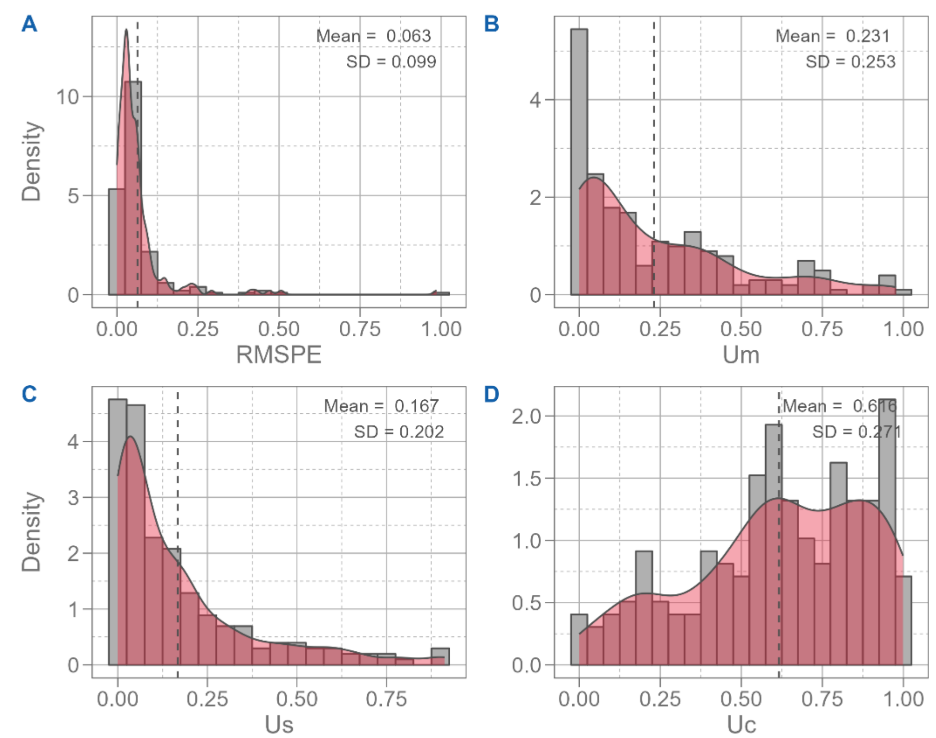

Figure 3 – Model Summary Statistics Distributions

From a sectorial point of view, Table 4 indicates a good fit for all sectors. The table's results suggest that Population, Finance, Electricity Generation, Government, and Infrastructure perform the best and that the Mortality and the Governance sector could benefit from some additional work for sector specific analysis. Once more, the statistical metrics are to be understood based on the population size (N) of each sector. Each sector's sample size affects the statistics' uniformity and meaning. Low sample numbers make fit interpretation challenging as a small amount of variables don't necessarily represent the overall dynamics of the sector. For a comprehensive picture, a larger and well-chosen population might be more adequate. Therefore, for a sector like Governance where population size is very small (equal to 1), data collection work and development of model structure could be performed in order to gain a deeper sectorial knowledge. Similar to the analysis of model statistics, it can be observed that the sector's error remains within acceptable limits. In cases where there is an error, a significant portion can be attributed to co-variation (UC). By examining the R^2 and RMSPE of each sector, it is evident that the model's simulated behaviour closely aligns with historical data. The accurate representation of historical data at the sector level indicates that the model effectively tracks medium to long-term trends, making it suitable for assessing the impacts of medium to long-term policies. Note that for the variable disaggregation of sectors, Annexe 3 has a complete table of variable statistics and graphical comparison of variable fit.

Table 4 – Aggregated Sector Summary Statistics

	Mean					Standard Deviation					
Sector	**R^2**	**RMSPE**	**Um**	**Us**	**Uc**	**R^2**	**RMSPE**	**Um**	**Us**	**Uc**	**N**
Agriculture	0.54	0.07	0.04	0.15	0.81	0.28	0.01	0.06	0.15	0.16	14
Balance of Payments	0.92	0.09	0.18	0.15	0.66	0.12	0.15	0.16	0.16	0.19	8
Biodiversity	0.68	0.06	0.10	0.20	0.70	0.30	0.06	0.09	0.22	0.31	4
Education	0.80	0.01	0.25	0.46	0.39	0.20	0.01	0.21	0.24	0.18	12
Electricity Generation	0.98	0.06	0.09	0.13	0.77	0.03	0.13	0.13	0.16	0.26	15
Emissions and Waste	0.70	0.07	0.19	0.14	0.68	0.38	0.06	0.23	0.14	0.25	11
Employment	0.82	0.08	0.37	0.13	0.50	0.24	0.22	0.30	0.10	0.31	19
Energy Consumption	0.35	0.08	0.06	0.26	0.68	0.31	0.06	0.12	0.28	0.30	13
Fertility	0.55	0.05	0.12	0.13	0.75	0.34	0.02	0.08	0.05	0.09	6
Finance	0.97	0.05	0.34	0.08	0.58	0.03	0.02	0.26	0.09	0.22	7
GDP	0.89	0.03	0.34	0.06	0.58	0.12	0.01	0.22	0.07	0.28	8
Governance	0.03	0.12	0.92	0.07	0.01						1
Government	0.97	0.04	0.26	0.05	0.69	0.03	0.01	0.13	0.07	0.16	6
Health	0.54	0.06	0.29	0.12	0.59	0.12	0.08	0.23	0.20	0.24	3
Households	0.96	0.10	0.69	0.02	0.29	0.05	0.08	0.26	0.04	0.25	6
Income Distribution	0.21	0.06	0.39	0.06	0.55	0.15	0.03	0.37	0.06	0.33	6
Industry	0.71	0.03	0.03	0.17	0.80						1
Infrastructure	0.91	0.00	0.11	0.21	0.69	0.09	0.00	0.17	0.22	0.16	4
Investment	0.95	0.06	0.39	0.06	0.54						1
Land	0.56	0.03	0.28	0.17	0.55	0.37	0.02	0.25	0.21	0.21	7
Material Consumption	0.71	0.05	0.27	0.10	0.63	0.34	0.03	0.32	0.15	0.29	9
Mortality	0.89	0.12	0.42	0.11	0.47	0.08	0.16	0.38	0.12	0.32	7
Population	1.00	0.00	0.27	0.39	0.34	0.00	0.00	0.22	0.30	0.12	3
Primary Energy Supply	0.89	0.09	0.12	0.16	0.72	0.14	0.14	0.23	0.28	0.32	10
Services	0.95	0.03	0.40	0.06	0.54	0.04	0.01	0.08	0.01	0.07	2
Vehicles	0.63	0.05	0.11	0.12	0.77	0.39	0.03	0.13	0.06	0.15	4
Water Supply	0.77	0.04	0.18	0.15	0.67	0.34	0.02	0.12	0.13	0.11	3
Water Withdrawal	0.30	0.05	0.19	0.39	0.49	0.07	0.04	0.24	0.35	0.30	7

Chapter 5: Results

5.1 iSDG Belgium adaptations

The objective of this section is to highlight the main structural adaptation of the iSDG model (v313) that I conducted as a way to meet **objective (1)** of the research.

5.1.1 Household/Income Distribution/Poverty sectors

The initial predefined automated calibration process of the iSDG model didn't conclude to meaningful results (very bad fit and unrealistic behaviour). Following the 'Fine-tunning calibration' process of the model guide, data issues where identified and fixed. In particular, 'disposable income' and 'household revenue' were badly defined in the data file which led to incorrect values for other variables. Moreover, doubts about the sudden changes in private savings led us to believe that 'Private capital and financial account' seem to have odd behaviour (80 billion change from 2002 to 2003). Therefore, we decided to smooth the data by defining it as a moving average.

After fixing the data issues, a reiteration of the predefined automated calibration process was conducted but yet again achieved poor results, even after using the recommended 'Fine tuning' techniques (change in optimization method, widen parameter space and manual calibration). Therefore, the fourth method of 'Fine tuning' was to be used. In that regard, first I conducted an analysis of all the different issues at hand, this led to the following list of problematic elements (besides KPIs): average income after tax by percentile, distribution of tax, distribution of subsidies and transfers, average direct tax pressure, proportion of adult population not receiving salaries and wages, distribution of the private consumption and saving by percentile. In the process of this analysis, the first realisation is that a well calibrated Gini coefficient doesn't necessarily mean a well calibrated average income after tax by percentile. However, the average income after tax is of crucial importance for other sectors. Therefore, a better indicator or additional data would be helpful to proceed to the calibration of this later. In search of helpful data, three data elements where found: income share by quintile (time series of 2000-2021 from WDI), direct tax pressure by quintile (time series of 2000-2021 from Eurostat) and average income by quintile (2010, 2014, 2017 data points from NBB).

These indicators were added to the model and compared to simulation results. The major issue then lied in the tax pressure distribution. In particular, the average tax pressure was extremely high 40%, which led the optimization to compensate in unrealistic manners (i.e. distribution of subsidies and transfers focused on higher classes or radical change from initial to present distributions). Therefore, an analysis of the potential formulation error was conducted for the average tax pressure. The analysis concluded in the fact that the numerator of the average tax pressure (which is supposed to represent the direct tax revenue) wasn't well defined as it wasn't taking into account that some of what's classified as 'other government' revenue doesn't necessarily come from tax. Therefore, the formulation was modified. Finally, following this modification and the collection of additional data, new optimization processes where defined and used to obtain realistic matches of historical data.

5.1.2 Material Flow sector

The initial model version (iSDG_v313) had the material flow sector structured in a very specific way based on the data availability of the time this specific sector was developed. This structure and the calibration process defined with it wasn't capable of replicating historical behaviour of Belgium. The major structural problem lied in the fact that the model categorised non-renewable materials (excluding fossil fuels) as construction materials and metal ores. Furthermore, based on this categorisation, construction materials and metal ores (consumption and extraction) were anchored on the cement consumption and production. However, Belgium's data doesn't show as much of a clear link between the two. Indeed, cement production decreases over time and construction material extraction increases.

To deal with this issue, the first reflection was to redefine the categorise of non-renewable materials considered. This quickly lead to use the same categorisation as the Material Flow Accounts developed by the UNEP, the International Resource Panel, Eurostat, and the OECD: non-metallic minerals and metal ores (European Commission. Statistical Office of the European Union., 2018; UNEP, 2021). The second reflection lied in the purpose of this sector: track the domestic material consumption and extraction. In other words, I needed to redefine on what basis non-metallic minerals and metals were consumed and extracted. To do so I split the task in two by considering extraction and consumption separately (see Figure 4 and Figure 5 for final results of structure).

In both cases the first question I asked myself was to what indicator (already existing in the model) is the non-metallic minerals and metals consumption and extraction linked to conceptually. For extraction the answer lied in the industrial production. Indeed, based on the model's definition of industrial production - which matches the definition of Statistical classification of economic activities' in the European Community (Eurostat, 2008; Eurostat., 2013) - it includes Mining and Quarrying which is by definition a good proxy for extraction rates. At the moment, in the model structure and data Mining and Quarrying production is embedded in the industry production, therefore I had to extract it. Note that the model is capable of defining this specific industrial sector separately and have a specific capital-employment-productivity structure dedicated to itself but given the scope of the project this was not conducted.

According to the availability of mining and quarrying monetary production, I computed the share it represented in industry's total production (which will remain exogenously driven), in order to have the monetary value of mining and quarrying production. The next step consisted in translating this monetary value in physical tonnes of materials. Note that the monetary value depends on the price of the commodity, however it has always been a conscious choice to make commodity prices exogenous across the model. Therefore, this sector was no exception and the translation from monetary value to physical terms was made exogenously by using the historical data in material and monetary terms to compute the ratio between the two. Finally, as a mean to distinguish the mineral to metal ores component of extraction the share of each component was computed based on historical data. Note that this later structural choice allows the structure to be generic even though Belgium's historical data for metal ores extraction is very close to zero. In other words, the total mineral and metals extraction could be attributed directly to the non-metallic mineral category.

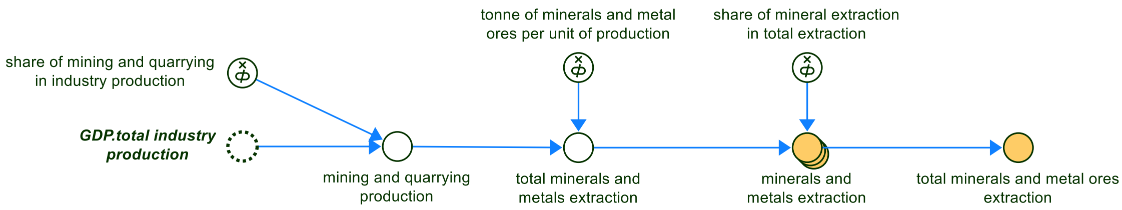

Figure 4 – Material flow sector adaptations (mineral and metal ores extraction)

As mentioned previously, the second issue that lied in the Material Flow sector was related to minerals and metal ores consumption. Once again, the first question I asked myself was to what other indicator in the model is this later linked to. To guide the reflection I looked deeper into the data available for Material Flow Accounts, which lead me to the RME tool developed by Eurostat (Eurostat, 2022, 2023) which is capable of disaggregating the final consumption in it's different components: private, governmental and caused by capital formation. Given the fact the model had all three of these components expressed in their monetary values the task was to translate the monetary values in physical terms. To do so, I used the RME model's result which runs for the European Union (as one single entity) to define the coefficient of raw material equivalent for each of the categorise mentioned and for the two material components (non-metallic minerals and metal ores). Note that ideally these coefficients should be specific to Belgium but given the data availability and the added value of having the disaggregation between private, public and capital formation, the European Union data had to be used as a proxy (for further details on the coefficients see supplementary material). This weakness shows to also become its strength as the data generated can be used for other European countries without further work.

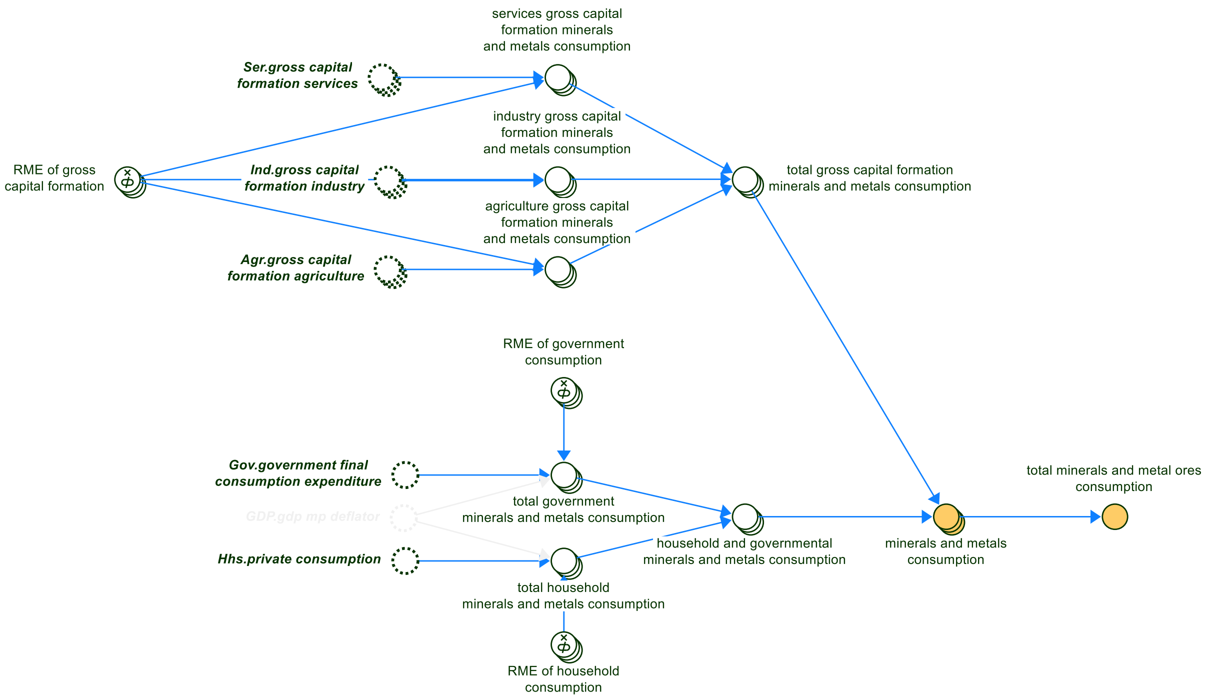

Figure 5 – Material Flow sector adaptations (minerals and metal ores consumption)

5.1.3 Emissions and Waste sector

For the Emissions and Waste sector, the previous model version disaggregated the total greenhouse gas emissions in three categories: fossil fuel energy emissions, non-energy related agriculture emissions and cement production emissions. Based on Belgium's emissions (Government of Belgium, 2022) this disaggregation isn't capable of providing an efficient coverage of the total emissions. Indeed, following the Intergovernmental Panel on Climate Change (IPCC, 2006) total greenhouse gas emissions should be classified as: energy; industrial processes and product use; agriculture, forestry and other land use; waste. As land changes emissions are taken care of separately in the model, industrial emissions and waste management emissions had to be added to the structure.

Concerning waste management emissions, the structure added is relatively simple as the model already accounted for the total waste generation. The only addition was to translate the waste generation in its emission equivalent as can be seen in Figure 6. To do so, given the historical data of waste generation and waste management emissions, the ratio between the two was computed and used as exogenous input. Concerning industrial production emissions, the objective was to link it to the industrial production. However, by definition not all industrial sectors are concerned by industrial production emissions as they represent emissions related to specific chemical processes. Therefore, the sectors concerned by such processes had to be identified. Based on the industrial sectors definitions and the IPCC guidelines, the choice of sectors were the following (named targeted manufacturing in the model): manufacture of coke and refined petroleum products, manufacture of chemicals and chemical products, manufacture of rubber and plastic products, manufacture of other non-metallic mineral products, manufacture of basic metals, manufacture of fabricated metal products, except machinery and equipment, manufacture of computer, electronic and optical products, manufacture of electrical equipment. The sum of these manufacturing sectors where then classified by type of industry (mineral, chemical, metal, others) and their respective monetary values were translated into emissions through emissions equivalent coefficient (for details see supplementary material).

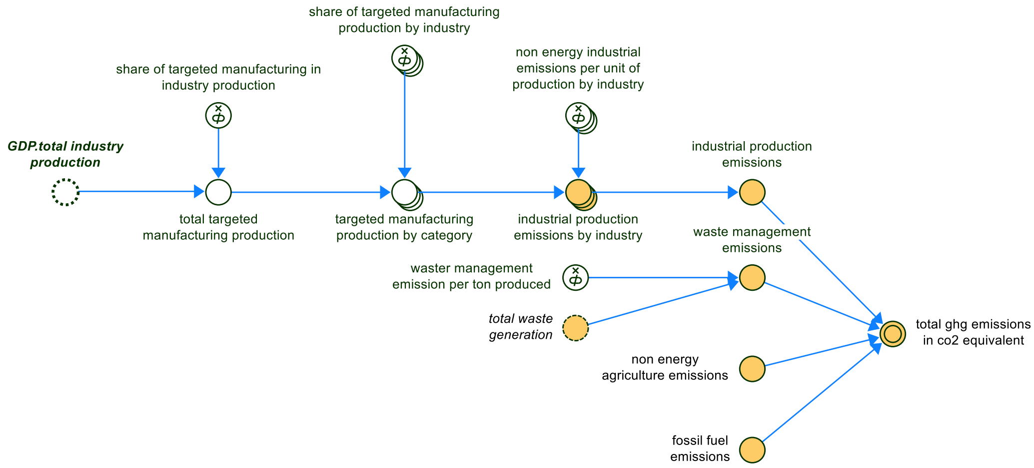

Figure 6 – Emission and Waste sector adaptations

5.1.4 Further Work

Going through the calibration process, lead to the identification of needed changes as detailed hereabove but the process has also revealed other changes that could be envisioned in a reiteration of the model's adaptation process. Among those potential additional changes, I distinguish two categories: disaggregation (or array) and structural changes. Concerning disaggregation changes, the following arrays could be modified given data availability and the analysis' purposes: engine, roads, expenditure line, and industry. The engine array could go beyond the internal combustion and electric vehicles to include hybrid and hydrogen cars. The roads array could be disaggregated in motorways and other roads (or national, provincial, communal roads). The expenditure line could be disaggregated following the European Classification Of the Functions Of Government (COFOG) to make sure model outcomes are relatable to the end user (Eurostat, 2019). The industry could be disaggregated in its five NACE categories (classification of economic activities in the European Union): manufacturing; mining and quarrying; electricity, gas and conditioning supply; water supply, sewage, waste management and remediation activities; construction.

Concerning structural changes, the following nine sectors could benefit from changes: education, health, infrastructure, vehicles, biodiversity, government, material flow, economic production and capital formation. For the education sector, the dropout rate could be affected by the income distribution. For the health sector, new indicators should be added, such as proportion of population over obesity threshold, healthy life years, proportion of processed food in diet. Moreover, the sector could benefit from explicitly having the dynamics of health care personnel and infrastructure. For the infrastructure sector, given the context of energy transition, the electricity transmission infrastructure could be added. Moreover, as mobility remains a major challenge for a high-income country like Belgium, infrastructure related to public transport lines (bus, metro, tram) and cycle paths could be added. For the same reason, the vehicle sector could benefit from the addition of a stock for the public transport fleet which could have an impact on the desired number of cars. For the biodiversity sector, new indicators could be defined in the model such as bird index, butterfly index, or mean surface acidity to have a better coverage of SDG 14 and 15. For the government sector, given the climate action context, including the dynamics surrounding the European Emission Trading System (ETS) would be an interesting addition. Finally, concerning the material flow sector, concepts that surround recycling and circular economy should be included given their importance in a high-income country like Belgium. Finally, given the availability of data concerning gross capital formation, gross capital consumption, total assets, compensation of employees, and operating surplus (disaggregated through economic sectors), a better estimation of the capital-investment nexus could be performed along with the wealth redistribution towards employees and capital holders.

5.2 Business As Usual scenario analysis

This section has objective to highlight the main outcomes of a Business As Usual scenario after the adaptation of the iSDG model, as a way to meet **objective (2)** of the research.

5.2.1 Economic Sector

As highlighted in Chapter 3, the BAU Scenario sets key policy variables such as the distribution of governmental expenditure for the period 2020 to 2050. For these variables, each expenditure item's future is assumed to remain at a static percentage of GDP by taking the final point of historical data (2020 in this case). Based on the endogenously computed GDP, Figure 7 shows that the total expenditure increased from around 126 billion LCU (Local Currency Units) to 267 billion LCU from 2000 to 2020, effectively more than doubling the amount. Between 2020 and 2050, the total expenditure quadruples to reach 1 230 billion LCU. This growth in total expenditure is mainly due to significant absolute increases in administrative, social benefits and health expenditures. However, it should be noted that the assumption made for expenditure might be too optimistic and that political change might see the expenditure distribution change radically. Moreover, the values are in nominal terms and are therefore dependent of the assumptions made on inflation. The results of the BAU scenario will depend on the actual expenditure values. It is possible that the total expenditure of the BAU scenario may not follow the same trend as GDP and be presented in absolute terms or adjusted to a gentler slope.

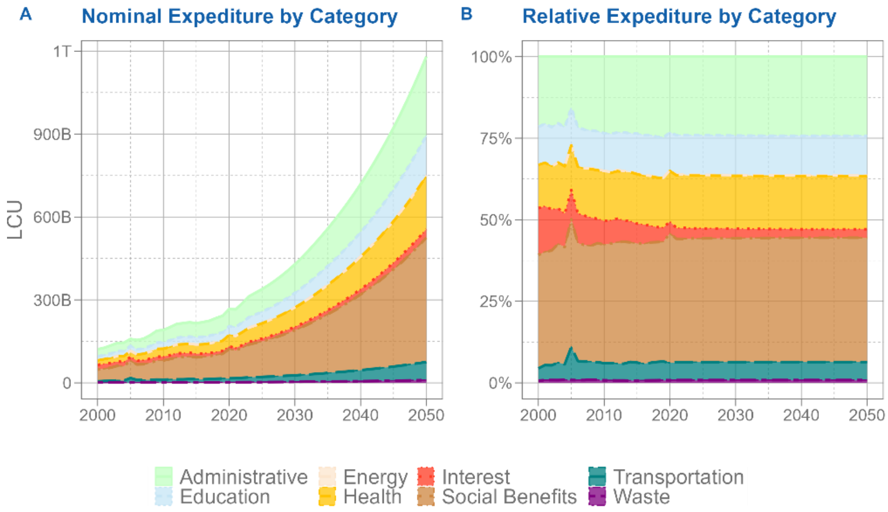

Figure 7 – Expenditure for BAU 2050

The economic sector results of the BAU scenario indicates significant growth. Historical data from 2000 to 2020 shows that Belgium's GDP increased from around 330 billion RLCU to 420 billion RLCU (Real Local Currency Units). As can be seen in Figure 8, from 2020 to 2050, the growth rate pursues its past trend, resulting in real GDP growing from 420 billion to 840 billion RLCU. According to the BAU scenario, the growth rate shortly recovers from the impact of COVID and is expected to catch up with its historical rate shortly after 2020. Figure 8B also illustrates that per capita GDP follows a similar trend as GDP since it struggles to grow around the 2008 crisis and COVID crisis but manages to get its growth rate back after 2020. The growth in GDP can be attributed to the continued capital accumulation of economic sectors and the accumulating contributions of education, infrastructure, life expectancy, and population to total factor productivity in the future as depicted in Figure 9. Indeed, the reinforcing loop of capital accumulation (R1) drives the behaviour to exponential growth, whilst being encouraged by the positive impact of employment and productivity.

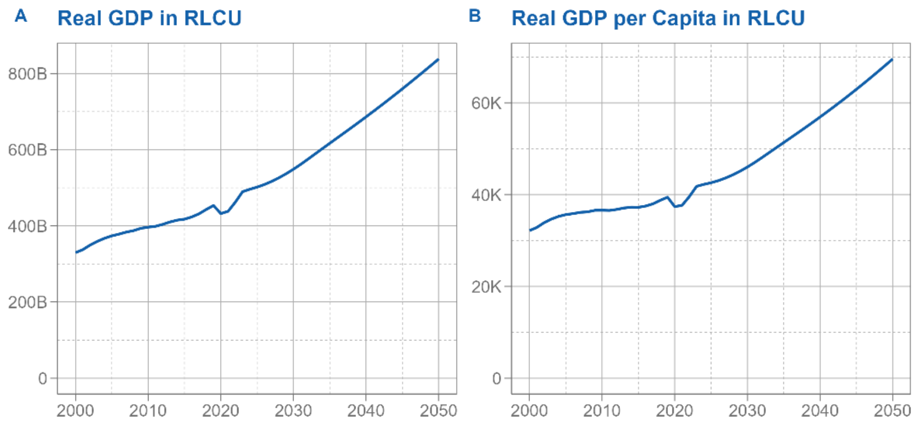

Figure 8 – GDP and GDP per capita Behaviour for BAU 2050

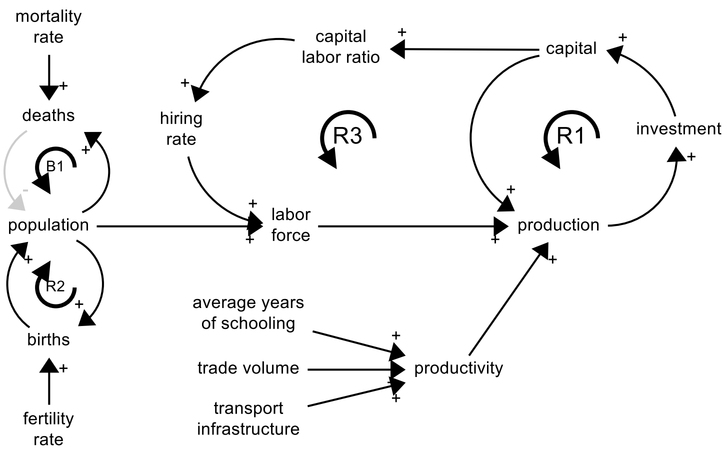

Figure 9 – Simplified CLD of the economic sectors' dynamics

The GDP figures can be decomposed in its three main economic sectors: agriculture, industry, and services (see Figure 10 for each sectors contribution to GDP). As can be seen in Figure 10A, historically production has majorly been caused by a high service production and small industrial production whilst agriculture represents an insignificant share of total production. In relative terms, we see that for the period 2020 to 2050 industry production takes 6 points off service production. Indeed, the industrial production starts growing at a faster rate than service production due to three factors: (1) continuous and growing investment in industrial capital, (2) productivity improvements due to the long-term benefits of high education attainment and proficient transport networks, (3) reemployment. Indeed, as can be seen in Figure 12, the share of investment going to industrial sectors gains 3 points off service sectors whilst the total (public and private) investment grows exponentially (Figure 11). This behaviour is caused by the R1 loop (see Figure 9) where investment increases as production increases, forming more and more capital. In turn, the capital increase leads to an increase in production which reinforces the initial increase. Concerning the increase in productivity, this later will increase due to the continuous efforts in the education sector but also to the increase in trade volume (as can be seen in Figure 11A) and in a growing life expectancy (see Figure 16C). Regarding the dynamics of reemployment, it is directly linked to the dynamic of capital through the R3 loop in Figure 9. Indeed, higher investment leads to more capital, which leads to the need of labour to operate capital. As investment come in and production starts to increase, it enables the industrial sector to propose increasingly attractive salaries to its employees relative to other sectors, therefore a new and growing workforce is created. These dynamic impacts the service sector which sees its labour force stabilise on one hand because of the industrial redevelopment but also because of the demographics dynamics causing the working age population to decrease and the retired population to increase (simplified B1 and R2 loops in Figure 9). Note that the service sector is the most quickly affected by the negative effects of an aging population given the fact that the industrial and agricultural sectors have a higher reliability on capital, but this effect could spread to these sectors if we were to look at the dynamics of the end of the century.

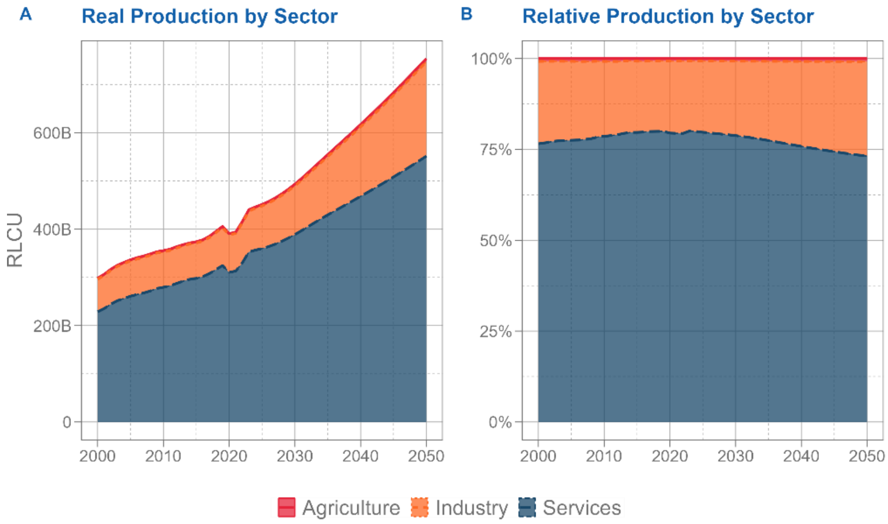

Figure 10 – Production Behaviour for BAU 2050

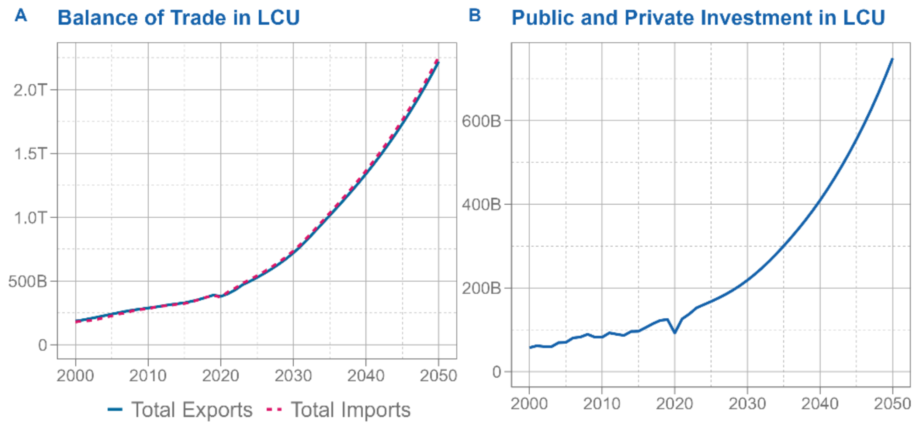

Figure 11 – Balance of Trade and Investment Behaviour for BAU 2050

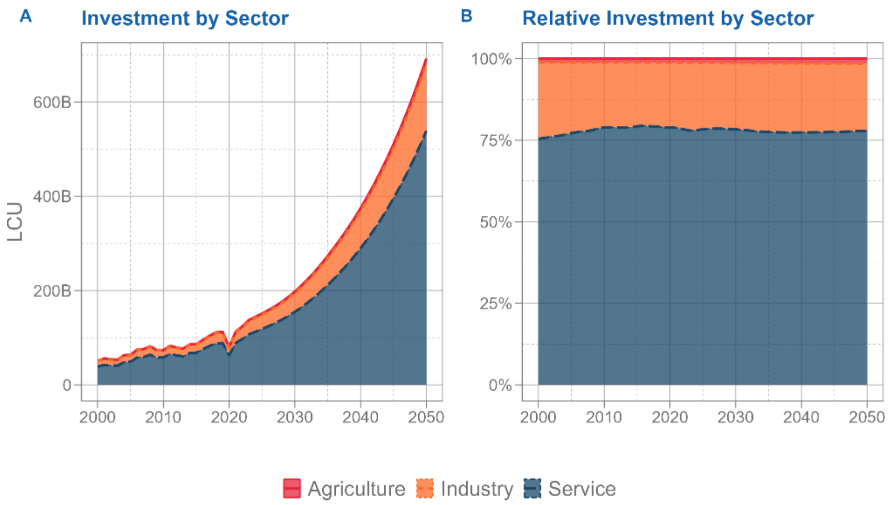

Figure 12 – Nominal Investment Behaviour for BAU 2050

Even though the agricultural sector in Belgium remains a small component of total production, the overall growth the sector has seen during the 2000-2020 period continues until 2050. Moreover, its growth rate increases significantly with production reaching over 6 billion RLCU in 2050 (Figure 13). Most of the growth in the sector, in absolute terms, is in livestock as we see that it gains 10 points in the total agricultural production from 2020 to 2050. The increase that the livestock production exhibits isn't matched by the crop production given the fact that the value added per tonne of crop production sees its growth rate slow down. The increase in livestock production can be attributed to both an increase in capital and in productivity. Indeed, the accumulated investment led to a substantial increase in capital, with more equipment farmers are capable of countering the decrease in available pastureland and a decreasing workforce. Concerning productivity, the positive impact of trade and governmental expenditure has allowed productivity to continue its recently upward trend and counterbalance the stabilising employment of livestock production.

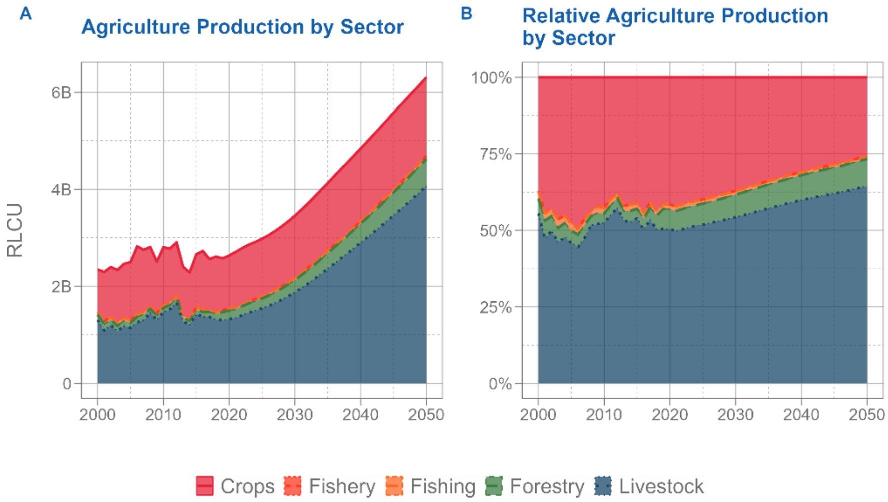

Figure 13 – Agriculture Production Behaviour for BAU 2050

Concerning public debt, the historical behaviour indicates higher expenses than revenues leading to a growth in the operating balance and public debt. In this BAU scenario this behaviour isn't resolved in the future (see Figure 15). Moreover, it gets alarmingly worst as the difference between expenses and revenues grows larger leading public debt to grow exponentially as can be seen in Figure 14A. Indeed, public debt more than triples from 2020 to 2050 as it goes from 640 billion LCU to more than 2 trillion LCU. On the other hand, the debt to GDP ratio indicates less alarming results as the ratio stabilises itself (see Figure 14B) due to the rapid growth in GDP. However, the ratio indicates that Belgium still produces less than it borrows until 2035, which could cause short to medium term destabilisation. Note that these results are in nominal terms and therefore are by nature sensitive to the inflation rate which in the BAU scenario is set constant and equal to the average of the last five years of the historical period.

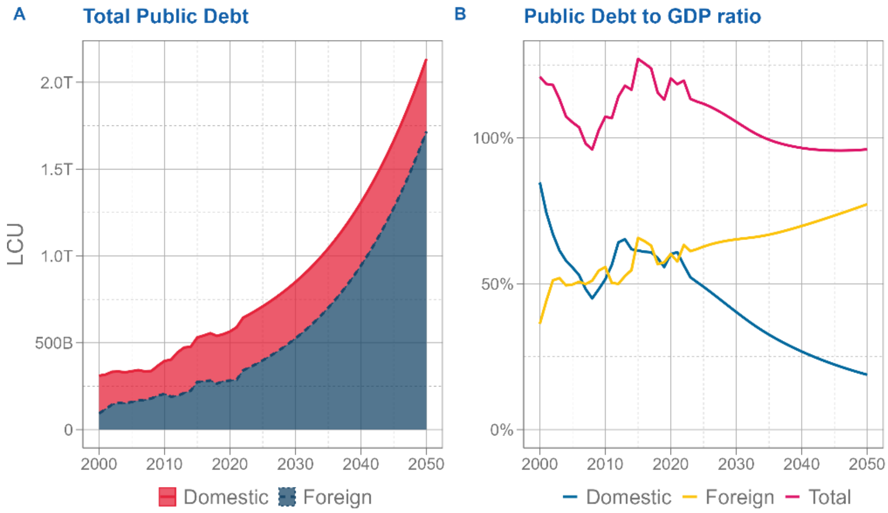

Figure 14 – Public Debt Behaviour for BAU 2050

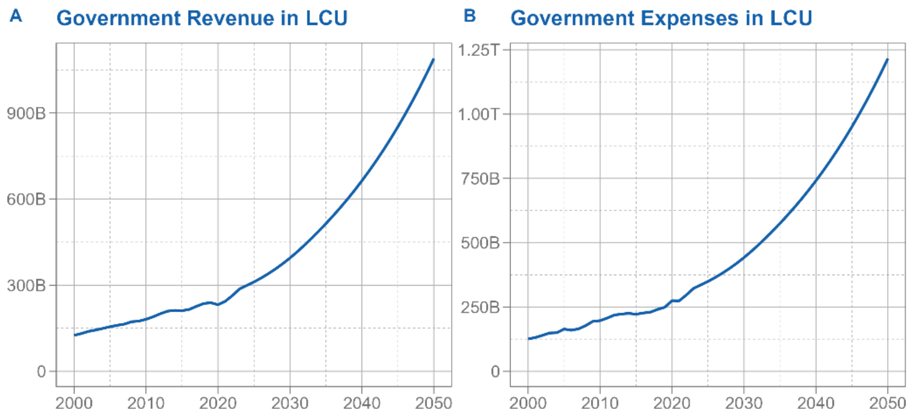

Figure 15 – Government Revenue and Expenses Behaviour for BAU 2050

5.2.2 Social sectors

Compared to the economic sector the population dynamics will not be following the historical trend in the future. Indeed, a clear s-shape curve appears as the total population growth rate slows down to reach close to zero by 2050 (see Figure 16A). By disaggregating by gender, we see that the female population remains larger than the men's but the gap slowly closes as men's life expectancy grows faster than women's (see Figure 16C). Looking at the age distribution of population (see Figure 16B) we see that the population will grow older as the stock of retired people increases to reach 2.7 million people in 2050. This shift in distribution causes the working age population to reach its peak around 2025 and gradually decrease thereafter. As for the school age population, we see that it also reaches its peak around the year 2025 and slowly starts decreasing after that which in the long run will have effects on the employment and productivity of the economic sectors as the workforce will get older and will have a harder time renewing itself. The observed transition in behavioural patterns can be attributed to a persistent decline in fertility rates. Retrospectively, the post-war era witnessed a significant surge in fertility rates, resulting in population growth. The shift occurring between 2010 and 2030 can be attributed to the gradual mortality of the cohort born during this period of heightened fertility. By looking at Figure 18, the causal relationship responsible for this development includes significant delays which explains why the changes in fertility rate only have effects in a longer horizon. Indeed, the increase in fertility rate that occurred after war, first affected the school age population, which increased significantly. As this cohort got older, the working age population increased until they slowly had to retire.

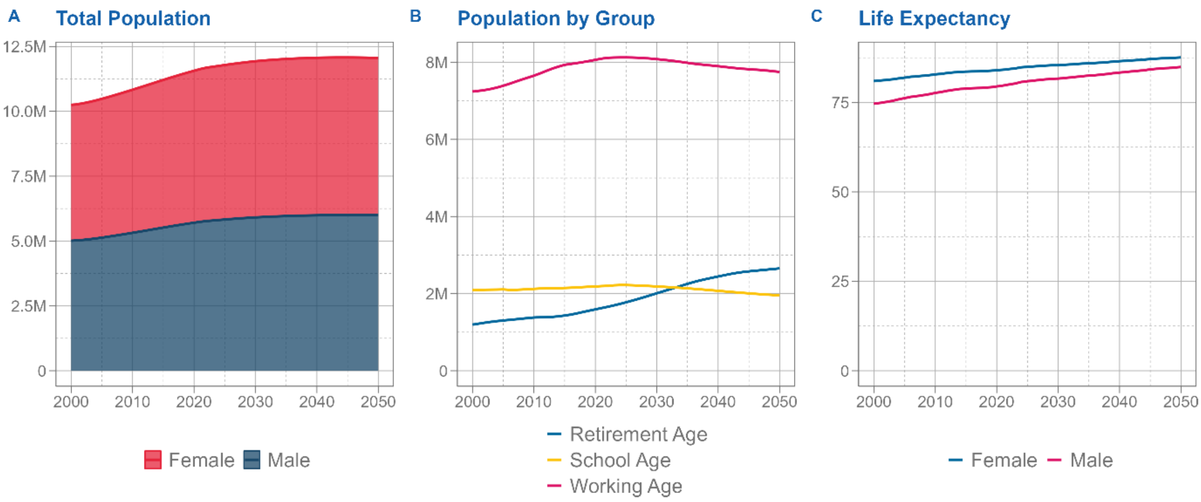

Figure 16 – Demographic Variables Behaviour for BAU 2050

Total employment continues to grow but at slower pace than historically as it goes from 4.98 million persons in 2020 to 5.47 million persons in 2050 (see Figure 17A). This growth is largely feasible due to the population and economic growth experienced in the BAU period; however, it's constrained by the decreasing working age population mentioned previously. As long as the working age population grows the total employment increases but as soon as the working age population decreases, we see that the employment's growth rate decreases leading to near stabilisation by 2050. In conjunction with increased reinvestment in the economy, the capital labour requirements also increase, thus generating additional employment opportunities from a supply driven effect (R2 loop in Figure 18). Figure 17B illustrates that despite this difficult growth in total persons employed, the ratio of employment to the working age population increases at a growing pace. This indicates that the working age population has a higher chance of finding a job given the fact that the retiring population have left vacancies. Moreover, this population group has a higher incentive to be working given the fact that society needs them to contribute to social benefits and transfers expenses such as pensions. Note that it is possible that accessibility of additional workforce through migration dynamics will contribute to continued employment growth.

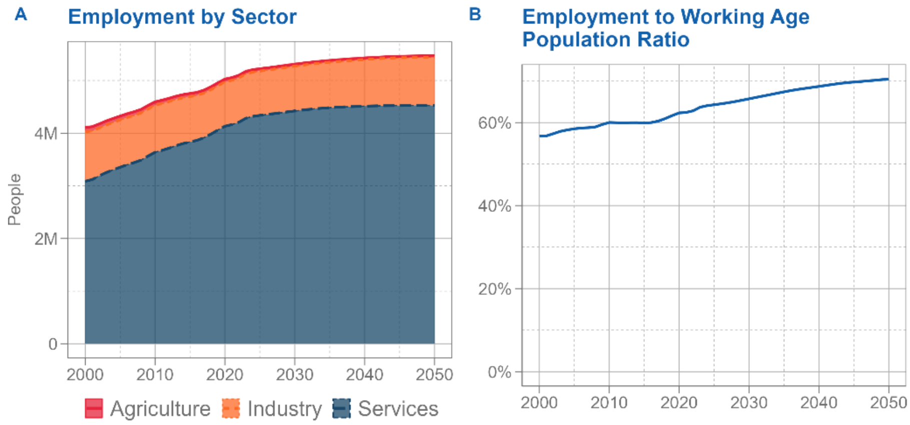

Figure 17 – Employment Variables Behaviour for BAU 2050

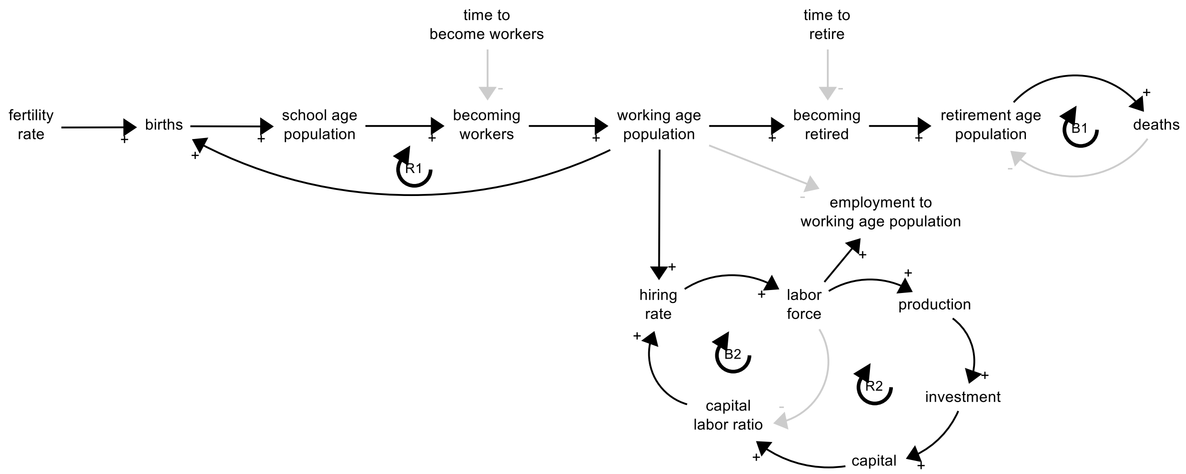

Figure 18 – Simplified CLD of social sectors' dynamic

For the education sector, we see that the key indicator - years of schooling - keeps its historical growth trend to go from 12.3 years to 14.2 years as can be seen in Figure 19. A growth explained by a slow increase in tertiary enrolment rate and a decrease in dropout rate caused by continuous and increasing expenditure in education. Moreover, we see that the gender difference that could be observed at the beginning of the century finally closes itself around the year 2025, which allows the gender gap in employment to close itself too.

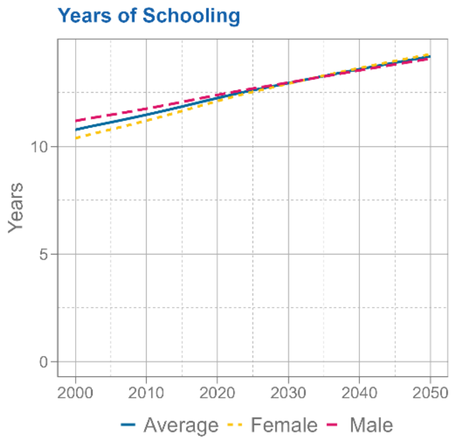

Figure 19 – Years of schooling Behaviour for BAU 2050

Assuming no changes in fiscal policy and distribution of social benefits, employment, education and social benefits will lead the income distribution to overall discouraging results as can be seen in Figure 20. Indeed, the higher classes (Q4 and Q5) see their income share either stabilise or increase whilst the mid to low classes (Q1-Q2-Q3) see their income share stabilise. In other words, the current fiscal policies and distribution of social benefits aren't sufficient to counterbalance the capital remuneration and higher salaries that high classes benefit from. As a result, by 2050 Q4 and Q5 will benefit from more than 55% of the overall wealth of the economy. This situation occurs regardless of the improvements in education and in the change in employment. Indeed, based on Figure 17B, one could think that more people employed in the working age population would lead low-income classes to access higher salaries. However, these potential benefits are discouraged by the current distribution of taxes and social transfers.

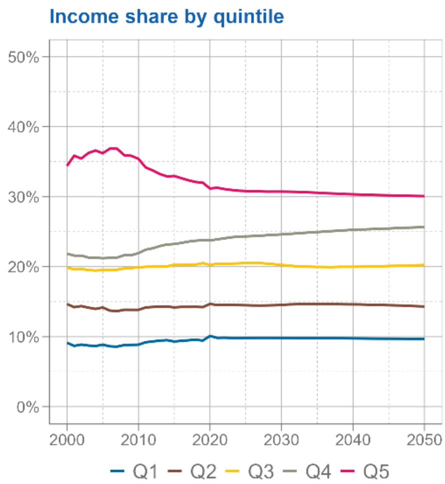

Figure 20 – Income Share Behaviour for BAU 2050

Looking at the transport dynamics, due to the increase in employment and therefore income, Belgium's total fleet of vehicle will keep on increasing similarly to its historical trend as can be seen in Figure 21A. This increase assumes that there is no significant measure made towards public transport that would slow down the trend of individual cars. Moreover, by assuming that the European targets are implemented, the composition of the fleet will change radically as we see that electric vehicles continue their historical exponential growth to replace the internal combustion engines. Note that this represents a significant industrial change and implementation issues in that regards might limit the optimism this scenario suggests. Nevertheless, this increase in electric vehicles leads to a significant decrease in fuel consumption and an increase in electricity consumption.

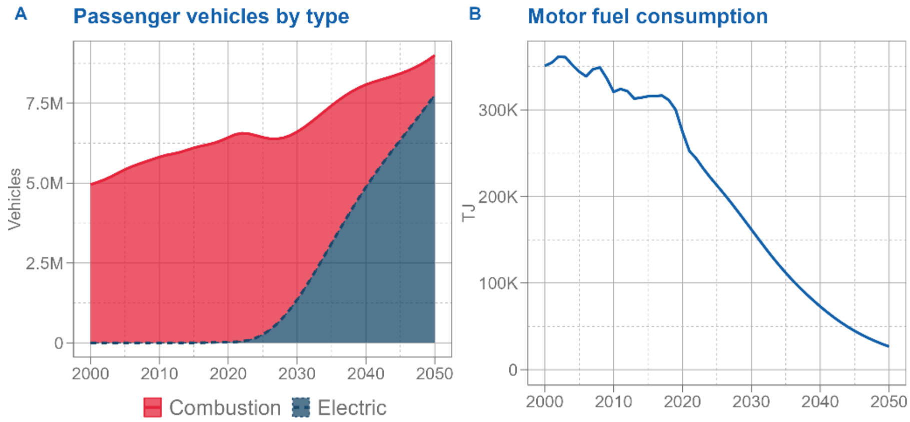

Figure 21 – Vehicles Variables Behaviour for BAU 2050

5.2.3 Environmental Sectors

For environmental sectors, performances are mixed as we have meaningful improvements, stagnation, and negative results. In that regard, the BAU scenario for land use doesn't exhibit significant changes in historical trends as can be seen in Figure 22A. Settlement areas stabilise, whilst forest increases by taking over a portion of pasture land. This development is coherent with population stabilisation and with the increasingly capital-intensive animal production. Indeed, as livestock farmers use more machinery and feed products, the demand for pasture land decreases leading pasture land to naturally transform into forests. In terms of water withdrawal, historically the decrease in industrial water consumption led to an overall decrease and stabilization as can be seen in Figure 22B. In the BAU scenario, there are two phases to distinguish: (1) the 2020-2030 period where the historical stabilization continues, (2) the 2030-2050 period where the growth in industrial and livestock production causes the overall water withdrawal to increase. These results are coherent with the behaviour of the economic variables.

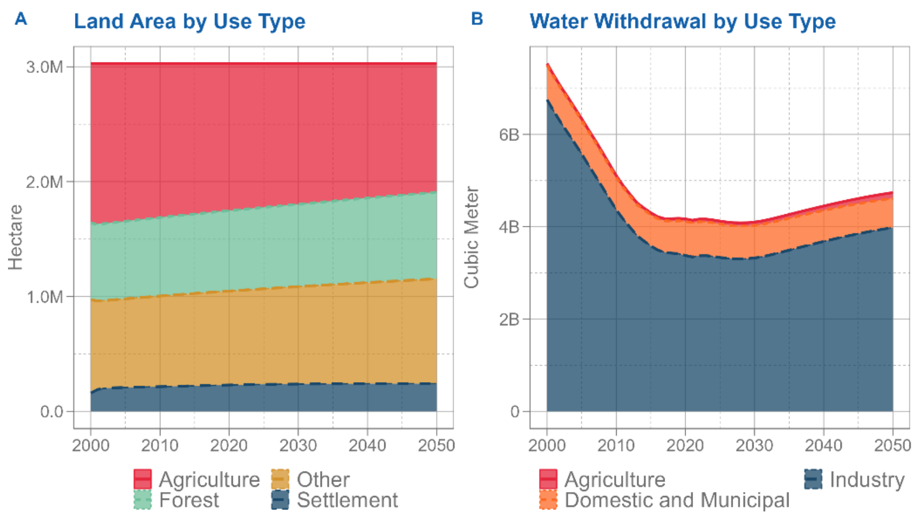

Figure 22 – Land Areas and Water Withdrawal by Use for BAU 2050

In terms of energy consumption, Figure 23 and Figure 24 provide results in terms of sectorial consumption and energy source consumption respectively. Historically, total energy consumption evolved from 1.74 million TJ in 2000 to 1.58 million TJ in 2020. The three sectors with the biggest share of that consumption were Industry, Transport and the Residential sectors which represent 28%, 17% and 22% respectively in 2020. In the total energy consumption, the dominant source used is oil representing 47% in 2020, followed by gas (28%) and electricity (19%). Moreover, as Belgium's energy production isn't sufficient to supply its needs in consumption, net imports remain at a very high level and follow the trend in consumption as can be seen in Figure 25. In the mix of imports, the integrity of oil and gas consumption come from imports. In terms of monetary value, total energy imports represent approximatively 5% of GDP in 2020 (fluctuating between 5% and 10% from 2000 to 2020).

In the BAU scenario, Figure 23A shows that the total energy consumption is going to increase, caused by the increase in industrial consumption. Results that are coherent with the economic indicators. However, these results are to be understood without any improvements in terms of energy efficiency in the industrial sectors. To include this component in the BAU scenario, additional data on the investment going towards energy efficiency improvements would be necessary. Besides the industrial increase, other sectors see their energy consumption stabilise at the exception of the transport sector which benefits from the change to electrical vehicles. In terms of energy source, oil see its consumption decrease as the transport component decreases which leads oil to represent 30% in the total mix. This decrease in oil consumption is offset by a substantial increase in gas and electricity consumption, representing 34% and 27% respectively in 2050. The industry's choice of energy source for redevelopment lies in the gas and electricity's suitability given the present industrial infrastructure and in the dynamic surrounding energy prices which both favour the consumption of gas and electricity over other sources. However, domestic gas production is still far below gas consumption leading to higher dependencies on imports.

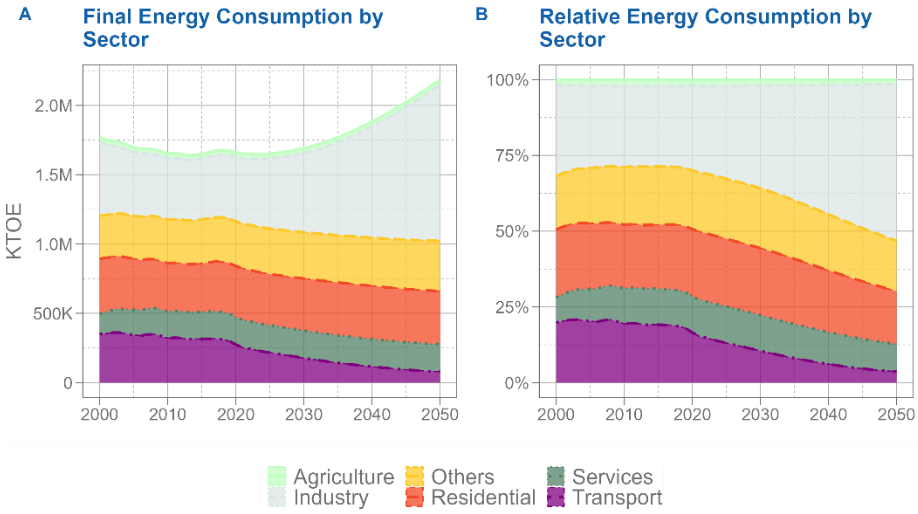

Figure 23 – Energy Consumption by Sector for BAU 2050

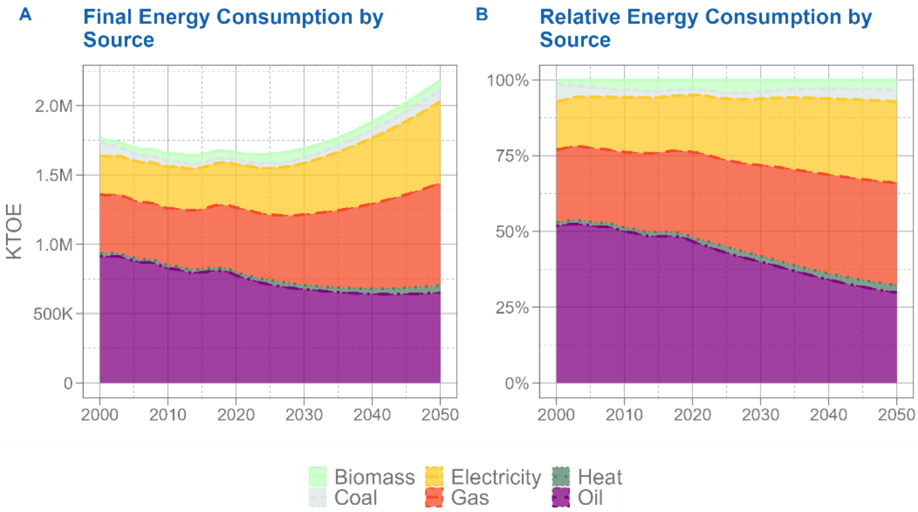

Figure 24 – Energy Consumption by Source for BAU 2050

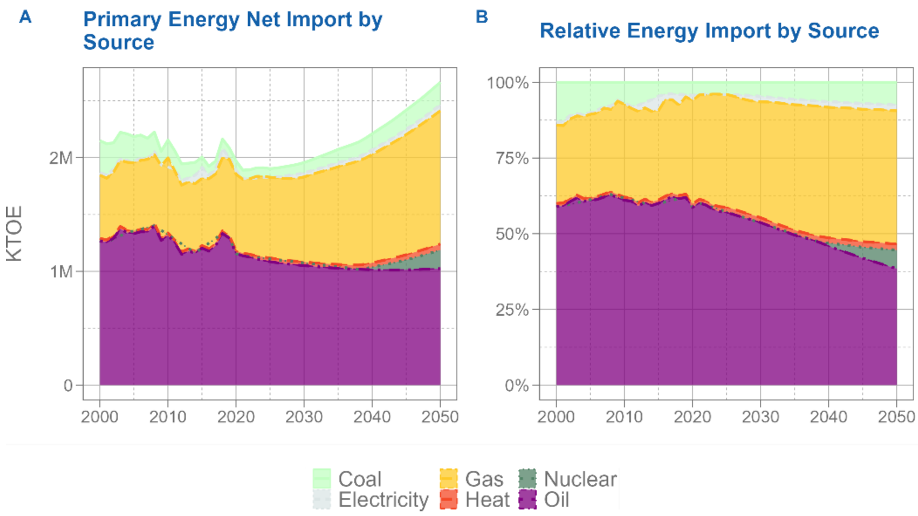

Figure 25 – Energy Imports by Source for BAU 2050

In terms of electricity production, the total capacity installed evolved from 14 GW to approximately 24 GW from 2000 to 2020 as can be seen in Figure 26. Dominated by gas and nuclear (both representing 40% of the capacity mix in 2000), the mix evolved to a redistribution of the capacity where gas represents 29%, nuclear 25%, wind 19% and solar 17%. However, because of the intermittence of renewable sources the electricity generation mix is still dominated by gas and nuclear which represent 31% and 40% of the total electricity generation respectively in 2020 as can be seen in Figure 27. In the BAU scenario, the cumulative trajectory of electricity generation maintains an upward trajectory, ultimately attaining a capacity of 47 GW by the year 2050. The future capacity mix is to be understood given the uncertain political context that governs the place of nuclear energy. Nevertheless, there is a notable surge in the proportion of renewable energies, with their contribution experiencing a substantial rise, culminating in a share of 50% by the year 2050. Specifically, solar and wind power exhibit a consistent expansion, reaching capacities of 9 GW and 12 GW, accounting for approximately 20% and 19% of the overall energy mix, respectively. On the other hand, alongside these encouraging outcomes in terms of climate action governance, there is a noteworthy expansion in the capacity of gas-powered generation, which undergoes a twofold increase from 2020 to 2050. Consequently, the electricity generation landscape is projected to persistently rely on non-renewable energy sources by 2050, with gas contributing to 28% and nuclear comprising 40% of the overall energy mix. Furthermore, a discrepancy exists between the rising demand for electricity and the capacity of electricity generation, resulting in a substantial reliance on imported electricity to meet the consumption requirements. Therefore, a significant portion of the consumed electricity continues to be sourced from external suppliers.

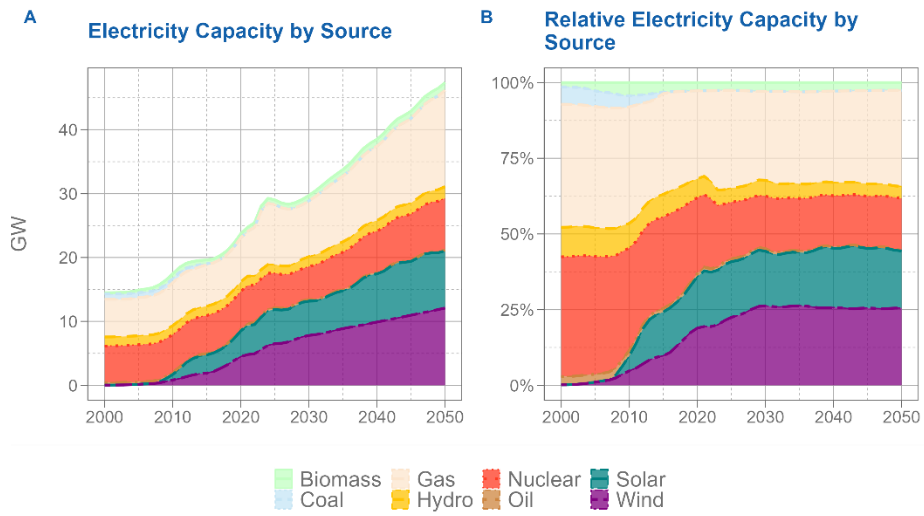

Figure 26 – Electricity Capacity by Source for BAU 2050

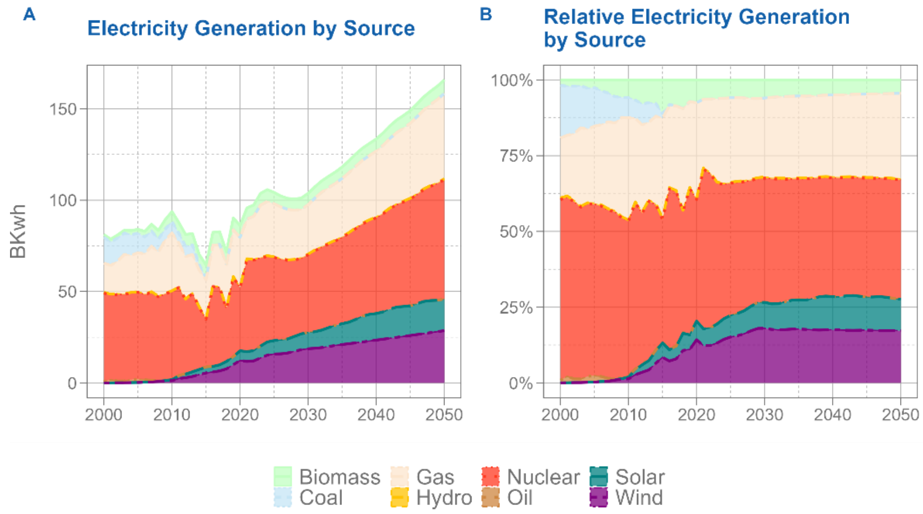

Figure 27 – Electricity Generation by Source for BAU 2050

Parallel to the escalated economic activities associated with the industrial sector and the subsequent augmentation in gas consumption, there is a concurrent rise in greenhouse gas emissions. This tendency marks a departure from the current pattern of decreasing emissions; however, it is important to interpret this within the context of assuming no improvements in energy efficiency, industrial processes, and agricultural practices. Historically, total emissions have decreased from 148 million tons of CO2 equivalent to 106 million tons of CO2 equivalent of which 74% comes from fossil fuel energies in 2020. In the context of the BAU scenario, the aggregate increase in greenhouse gas (GHG) emissions can be primarily attributed to the intensification of emissions stemming from (1) non-energy-related processes within the industrial sector and (2) agricultural emissions from livestock. It is crucial to recognize that this outcome necessitates a more nuanced examination, one that demands a detailed delineation of economic activities within specific industrial sectors accountable for such emissions (e.g., chemical production, cement production). Incorporating such sector-specific analyses into the model structure by disaggregating them from the overall industrial production would provide a more rigorous approach to assessing and potentially revising these emissions projections. Regarding agricultural emissions, the historical emission levels demonstrate a persistent stability, corresponding to the steady nature of livestock production measured in tonnes. However, the introduction of increasing economic capital and the continuous advancement in productivity stimulate a subsequent amplification in livestock production, resulting in a parallel escalation of emissions which reach alarming levels (12% of total emissions in 2050 as opposed to 6% in 2000).

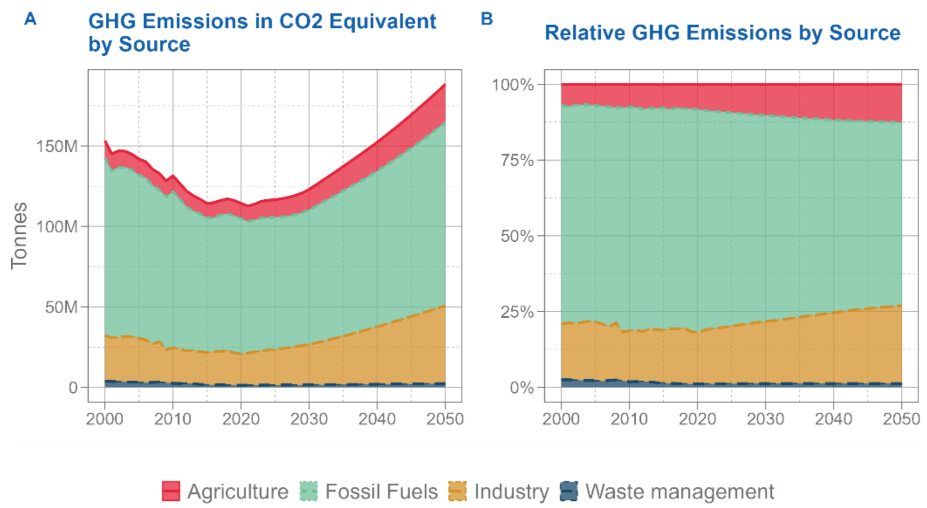

Figure 28 – Emissions Behaviour for BAU 2050

In terms of material consumption, total domestic material consumption has decreased in the past and slowly stabilised in the most recent years as can be seen in Figure 29. The distribution of this consumption is mainly between minerals, fossil fuel and crops representing approximately 35%, 20% and 27% respectively in 2020. In the context of the BAU scenario, the industrial development analysed within the economic sectors analysis exerts ramifications that extend beyond energy consumption and greenhouse gas (GHG) emissions. It also exerts a notable influence on material consumption, as evidenced by the exponential surge in total domestic consumption, surpassing 250 million tonnes of raw material equivalent by 2050. A significant proportion of this augmentation is attributed to the escalating demand for minerals, necessitated by the capital formation requirements of the industrial sector. The observed consumption trend is accompanied by a progressive rise in the extraction rate of minerals, as depicted in Figure 30. However, it is important to interpret the outcomes of extraction within the context of assuming the absence of stock limitations or infrastructural factors that hinder the extraction rate. Further endeavours in structural modelling and data analysis pertaining to these aspects hold the potential to modify the presented results. Another impact of the economic development is on waste generation as can be seen in Figure 31. The growth trajectory of gross domestic products (GDP) aligns with a concomitant upsurge in disposable income, consequently leading to an increase in private consumption. As private consumption continues to expand, the generation of waste also escalates, ultimately reaching unsustainable levels of per capita waste generation. This development further induces the need for collection and treatment infrastructure.

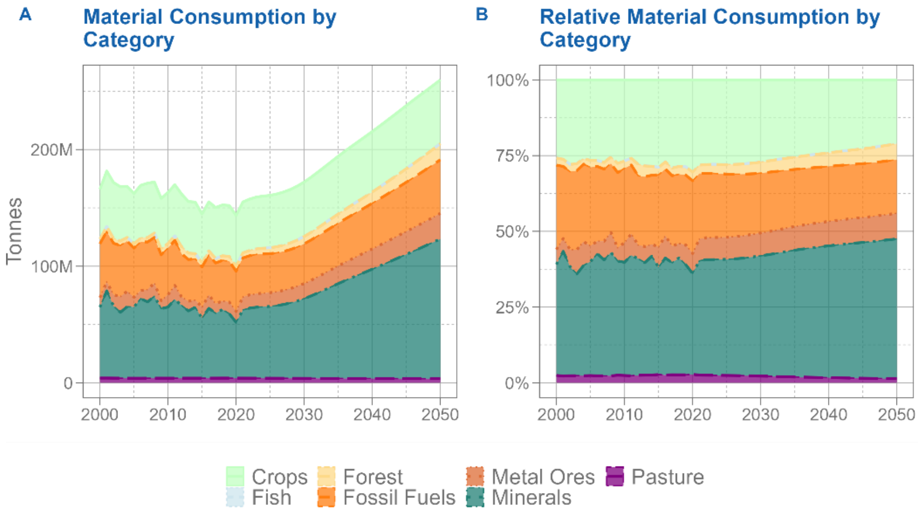

Figure 29 – Material Consumption Behaviour for BAU 2050

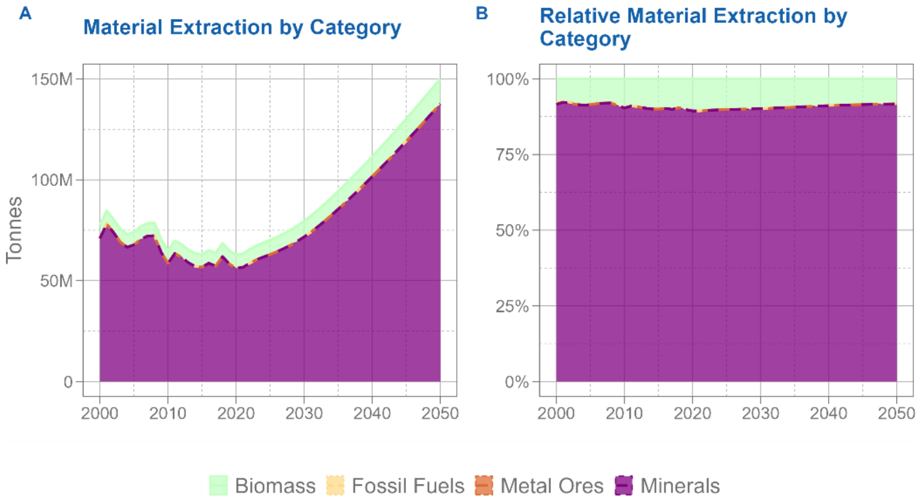

Figure 30 – Material Extraction Behaviour for BAU 2050

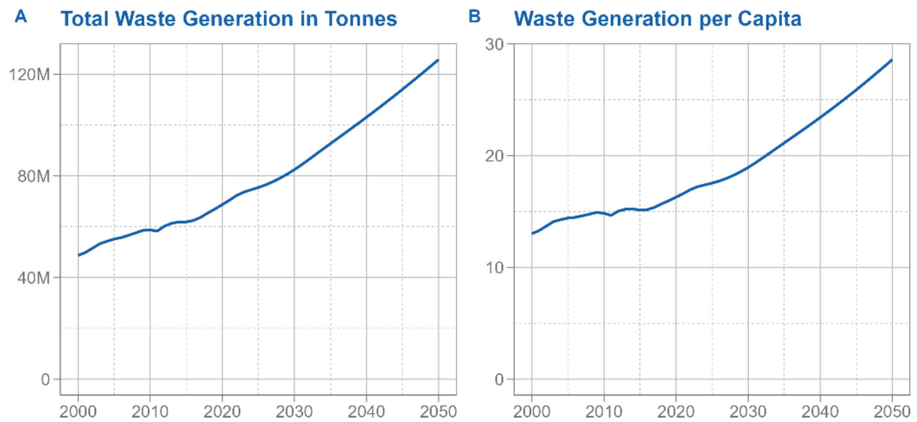

Figure 31 – Waste Behaviour for BAU 2050

5.2.4 Summary

With regard to economic sectors, the production outcomes in the BAU scenario present promising results, as growth continues to prevail across all sectors. Notably, the industrial sector demonstrates a higher growth rate compared to other sectors. The impacts of the COVID pandemic are promptly addressed. However, from a governmental perspective, expenditures persistently surpass revenues, resulting in unsustainable levels of debt.

With respect to social sectors, the employment sector exhibits positive performance, evident in a substantial increase in the ratio of employed individuals to the working-age population. However, this outcome stems from the underlying dynamics of an aging population, which may inadvertently create a sense of undesired pressure on younger population groups to engage in increased work activities. Consequently, it is imperative to concurrently monitor indicators of quality of life to comprehensively evaluate the implications of these results. In terms of income distribution, the findings present less favourable outcomes, as the income disparity widens between higher and lower socioeconomic classes, regardless of the improvements in average years of schooling.

In terms of environmental sectors, it is essential to address the concerning negative consequences associated with the growth of the economy. Numerous dimensions of the environment experience adverse impacts, including water withdrawal, energy consumption, greenhouse gas emissions, material consumption, and waste generation. The significant contributor to these effects is the growth of industrial production, which results in elevated water demand, amplified consumption of fossil fuels (particularly imported gas), emissions arising from industrial processes, and intensified mineral consumption for capital establishment. As a consequence of the expanding economy, there is a parallel increase in private consumption, consequently leading to higher levels of waste generation.

Chapter 6: Conclusion

To conclude this paper, I will address in a succinct fashion how the research objectives were met and how the research questions were answered. Second, I will describe a few personal reflections for further work along with broader implications of the analysis performed.

6.1 Research objectives

> **Objective 1:** adapt the iSDG model to Belgium as a way to provide a first systemic, integrated, transparent, model for Belgium's sustainable development policy planning.

The final model used for the analysis of Belgium's SDG performances is a fully calibrated iSDG model. Calibration used methods such as partial model testing and a series of behaviour reproduction tests, all of which are reported in Chapter 3 and Chapter 4. A calibration process that wouldn't have been possible without the preliminary data collection and the iteration between the two processes. Indeed, the iSDG model requires a large quantity of data for parameter values, historical time series comparison, exogenous time series inputs (temporary for calibration purposes and permanent for simulation). A first data set was collected through the Millennium Institute's automated process, which needed manual gap filling and error revision before and during the calibration process.

Overall, the adapted model can replicate historical behaviour modes of Key Performance Indicators with high accuracy: R^2 of 0.76 and RMSPE of 0.06 when looking at model aggregates. Note that a more complete statistical analysis was performed and reported to assess the fit at sectorial and variable levels in Chapter 4 and Annexes respectively. Moreover, newly developed structures were added for the "Material Flows" sector and the "Emissions and Waste" sector following IPCC, UNEP, OECD, and Eurostat's frameworks for a conceptually more accurate representation of non-metallic mineral flows and a better coverage of greenhouse gas emissions (in particular: industrial processes and waste management emissions). The process and results of these changes are documented in Chapter 5. Given the system dynamics nature of the iSDG model, this later modelling method allows systemic analysis that integrates stocks, flows, delays, and feedback loops in a transparent way as discussed in Chapter 2 and Chapter 3.

> **Objective 2:** analyse the development of key indicators in a Business As Usual (BAU) scenario looking at the 2050 horizon as a way to explore the interactions and interconnections between the SDGs in a qualitative and quantitative fashion.

The BAU scenario results are relatively positive for the economic sectors with the exception of unsustainable levels of debts. Indeed, all three main sectors (services, industry and agriculture) recover from the COVID pandemic and regain their historical growth rate as analysed in Chapter 5. In the case of industry, it surpasses its historical growth rate and gains significant importance in the economy by 2050 (25% of total production as opposed to 19% in 2020). Concerning social sectors, total employment suffers from the underlying demographic phenomenon of aging population which leads total employment to stagnate by 2050. However, given the aging population, there is a higher proportion of the working age population that enters the workforce to compensate for the increasing retirement. On the other hand, income distribution progresses in the wrong direction as higher income classes continue to benefit from the combined higher salaries and capital gains. This later dynamic results in the highest two quintiles capturing 55% of the total wealth.

Finally, concerning environmental sectors, the BAU scenario suggests poor performances. Indeed, the economic growth continues to have negative effects in terms of energy consumption, material consumption, greenhouse gas emissions, and waste generation. For energy consumption, the overall growth of the economy leads to higher energy consumption which without drastic changes in energy sources will continue to be dominated by fossil fuels (more than 80% of total energy consumption). In particular, the industrial growth leads to a higher consumption of natural gas, further reinforcing the import dependency (representing over 5% of GDP by 2050). This increase in fossil fuel energy consumption accompanied by an increase in emitting industrial process (non-energy related) leads to higher emissions. Moreover, even though the BAU scenario doesn't include any efficiency improvements, it alerts on the fact that the efficiency improvements needed to reach climate goals would be beyond reasonable if let alone. Therefore indicating that efficiency improvements must be combined with other policies to achieve the set goals. With regards to material consumption, the continuous formation of fixed capital needed to sustain economic growth leads domestic consumption to grow from 160 million tonnes in 2020 to 260 million tonnes in 2050. Finally, as more economic wealth is generated, households benefit from a higher income which allows them to consume at a higher rate. Without any changes in consumption behaviour and product assembling, total waste generation increases to nearly 1 tonne of waste per capita per year.

Sub objective 1: Extending and broadening Millennium Institute's collection of iSDG adapted models to a high income country.

Sub objective 2: Providing a sound foundation of structure for future policy structure that could be used in similar national planning contexts.

The resulting iSDG Belgium model is now part of the collection of the iSDG adapted model. An adapted model that enabled a discussion between the Millennium Institute and the independent governmental think tank, the *Bureau Fédéral du Plan*, which asked for a presentation of the results after a broader discussion of the model's methodology and capacities. Allowing system dynamics and the iSDG model to gain visibility and interest outside the academic world. The adaptation process of the iSDG model both highlighted necessary changes to the core model of the Millennium Institute and started a reflection on future work needed. Changes that the modelling team and the various partners of the institute have already benefited from. Indeed, given the generic formulation of the changes in the "Material Flow" sector and in the "Emissions and Waste" sector, the structure may be carried out in other national planning contexts.

6.2 Further discussion

As detailed in Chapter 5, the final model version and the results that depend upon it are the outcome of a first iteration of model calibration, therefore contains notable limitations which could lead to significant improvements if dealt with. Amongst those limitations and given the results' dependency to the dynamics of the capital-production nexus, further work should be directed to modify the model's structure/calibration process to incorporate data concerning capital and production's labour share (by using Eurostat's datasets for gross capital formation, gross capital consumption, total fixed assets, compensation of employees, and operating surplus). In addition, efforts should be directed to expand the list of SDG indicators to a more adapted list for high income countries. For example, the analysis would greatly benefit from the dynamics of circular economy or emission trading schemes.

Given the scope of the model and the topic it's addressing, I would like to stress that the context in which the modelling work takes place is of crucial importance and that a participative approach to the model's development but also to the results analysis is most likely what would bring out the best from the model. Indeed, in the process of the iSDG model's adaptation, what enabled the most significant and fruitful changes is the continuous diversity of perspectives. This leads me to believe that if the model was to be used in a national planning context, involving experts from different disciplines and level of governance along with on-the-ground stakeholders would enable more interesting results and potentially more meaningful actions.

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Annexes

Annexe 1 - Data collection process

Phase 1: Automated time series collection through first set of databases

Phase 2: Manual time series collection through second set of databases

The manual time series collection seeks to fill in the data gaps that still arise after Phase 1. In this context, gaps are defined as entire time series missing, certain values missing, a need for a more detailed quantification, a validation from local source. The gaps are first identified and listed, then addressed one by one in an orderly fashion, following the sectors in the model. Depending of the nature of the variable certain databases were prioritized. For example, the National Bank of Belgium's database was prioritised for data related to government expenditure. Once the variable is identified in the available databases, we undergo two validation check before collecting the data. First, we check the concordance of definitions between the database's and the model's definition. For that, on one hand, the Meta Data of each database was analysed and compared to the definition of the iSDG Online Documentation. On the other hand, if such Meta Data is not available, we consulted experienced modellers and data practitioners. As a second methodological check, units from the database and from the model were compared to make sure the variable is expressed correctly. Finally, the collection was made by exporting the data and incorporating it in the 'iSDG_Belgium.xlsx' file, under specific sheets depending of the source and sector.

Phase 3: Manual estimation, calculation, adjustment of manual time series collection

Based on the collection of Phase 2, some of the data collected needed rework to be able to be used. This rework takes the form of estimation, calculation and adjustment whilst documenting each operation. For example, data for passenger and commercial vehicles was needed in its disaggregate form (based on engine type: electric or internal combustion). The local database STATBEL was identified and was capable of providing this dataset but in an even more detailed engine type disaggregation (petrol, diesel, gas, hybrid, electric, etc). Therefore the calculation were defined in order to aggregate the different dimensions and match the model's definitions. Each of these manual changes are made fully transparent by following the notes referenced in column AK to AT of the 'Data' sheet and the sheets mentioned in these later columns.

The spreadsheet 'iSDG_Belgium.xlsx' contains all the data used in the model. The file is structured as described in Table 5.

Table 5 – Summary of Data Sheets

Sheet Categories	Sheet Name	Sheet Description
Parent files	Start	Sheet that gives the possibility to export sheets and set initial year in a user friendly fashion. Moreover, it contains the legend.
	Data	Sheet that serve as the parent file. It contains the data of the Exo, Hist, Init, Input, and Sources sheet. Modification are to be made in this sheet only. Moreover, definition notes, meta data, sources, etc can also be found in this sheet.
	SDG Targets and Zero Levels	Sheet that defines the targets for 2030 and the levels for which performances will be compared to (zero level) for each of the Sustainable Development Goals
Automated files	Exo	Sheet that contains temporarily external variables used for calibration (uses these values instead of the values in the model). This disables the value that the model would otherwise compute if it were active. If Stella does not use this sheet, then all values are endogenized.
	Hist	Sheet with time series that can be used as a benchmark against which to compare and calibrate the model's output values. When the model is properly calibrated, this is the Hist run.
	Init	Sheet that contains the model's initialization and parameterization values (corresponding to the model start year). The Parameters csv file is used in lieu of this throughout the calibration procedure.
	Input	Sheet that contains a time series of the model's externally-inputted variables. Note that Stella interpolates the intermediate years, and the last value is use as a fixed value for future values. The model constantly employs this sheet.
	Sources	Sheet that contains all the sources for each variable and parameter values used in the 'Data' sheet.
Additional files	Others	Series of sheets that correspond to specific data that are then used in the 'Data' sheet. It's in these sheets that additional information concerning the estimation, calculation, adjustment can be found.

Annexe 2 - Behaviour reproduction analysis

Annexe 2.1 - Statistical fit tables

Table 6 – Variable Statistics of Goodness of Fit

Variable	N	Data Coverage	R^2	RMSPE	Um	Us	Uc
Agr.crops production	20	0.95	0.47	0.08	0.00	0.00	1.00
Agr.crops production by crop[crop 1]	20	0.95	0.47	0.09	0.00	0.00	0.99
Agr.crops production by crop[crop 2]	20	0.95	0.60	0.10	0.01	0.07	0.92
Agr.crops production in tonnes[crop 1]	20	0.95	0.22	0.07	0.01	0.02	0.97
Agr.crops production in tonnes[crop 2]	20	0.95	0.54	0.07	0.02	0.25	0.73
Agr.fish capture production	20	0.95	0.83	0.06	0.01	0.03	0.96
Agr.fish production in tonnes	20	0.95	0.79	0.06	0.02	0.01	0.97
Agr.forestry production	20	0.95	0.93	0.06	0.01	0.27	0.72
Agr.forestry production in cubic meters by wood type[wood 1]	20	0.95	0.43	0.06	0.04	0.31	0.64
Agr.livestock production	20	0.95	0.77	0.06	0.15	0.17	0.68
Agr.livestock production in tonnes per hectare[animal 1]	20	0.95	0.77	0.06	0.16	0.12	0.72
Agr.livestock production in tonnes[animal 1]	20	0.95	0.60	0.06	0.13	0.09	0.79
Agr.yield[crop 1]	20	0.95	0.00	0.07	0.02	0.41	0.56
Agr.yield[crop 2]	20	0.95	0.10	0.08	0.01	0.37	0.61
BDv.fish resources availability share	19	0.90	0.41	0.07	0.11	0.06	0.83
BDv.proportion of fish stocks sustainably exploited	19	0.90	0.42	0.13	0.06	0.25	0.69
BDv.proportion of territorial waters formally protected	21	1.00	0.90	0.03	0.01	0.00	0.99
BDv.red list index	21	1.00	0.97	0.00	0.23	0.50	0.28
BoP.capital and financial account balance	21	1.00	1.00	0.03	0.24	0.33	0.43
BoP.current account balance	21	1.00	0.89	0.47	0.00	0.03	0.97
BoP.net current transfers	21	1.00	1.00	0.03	0.46	0.02	0.52
BoP.private capital and financial account	21	1.00	1.00	0.03	0.22	0.14	0.64
BoP.public current transfers	21	1.00	0.98	0.03	0.33	0.13	0.54
BoP.total export	21	1.00	0.95	0.06	0.11	0.04	0.85
BoP.total export share of gdp	21	1.00	0.63	0.04	0.00	0.47	0.53
BoP.total import	21	1.00	0.95	0.07	0.12	0.04	0.84
Edu.adult literacy rate[FEMALE]	21	1.00		0.00	0.63	0.37	
Edu.adult literacy rate[MALE]	21	1.00		0.00	0.10	0.90	
Edu.average adult literacy rate	21	1.00		0.00	0.45	0.55	
Edu.average years of schooling[FEMALE]	21	1.00	0.98	0.01	0.00	0.63	0.37
Edu.average years of schooling[MALE]	21	1.00	0.98	0.02	0.34	0.57	0.09
Edu.primary net enrollment rate[FEMALE]	18	0.86	0.49	0.01	0.41	0.19	0.40
Edu.primary net enrollment rate[MALE]	18	0.86	0.49	0.01	0.38	0.23	0.39
Edu.secondary net enrollment rate[FEMALE]	18	0.86	0.73	0.01	0.07	0.57	0.36
Edu.secondary net enrollment rate[MALE]	18	0.86	0.71	0.01	0.02	0.50	0.48
Edu.tertiary gross enrollment rate[FEMALE]	20	0.95	0.95	0.03	0.11	0.19	0.70
Edu.tertiary gross enrollment rate[MALE]	20	0.95	0.88	0.04	0.39	0.09	0.52
Edu.total average years of schooling	21	1.00	0.98	0.01	0.11	0.69	0.20

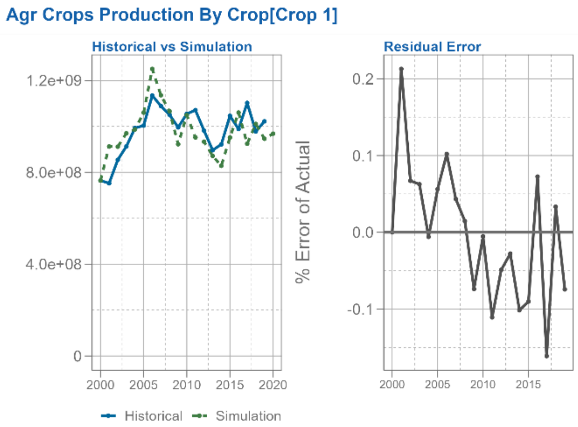
Variable	N	Data Coverage	R^2	RMSPE	Um	Us	Uc
ElG.electricity generation by source[BIO]	21	1.00	0.99	0.05	0.02	0.01	0.97
ElG.electricity generation by source[COAL]	21	1.00	0.96	0.51	0.36	0.23	0.41
ElG.electricity generation by source[GAS]	21	1.00	0.99	0.02	0.01	0.02	0.97
ElG.electricity generation by source[HYDRO]	21	1.00	1.00	0.00	0.01	0.02	0.96
ElG.electricity generation by source[NUCLEAR]	21	1.00	1.00	0.00	0.02	0.01	0.98
ElG.electricity generation by source[OIL]	21	1.00	1.00	0.03	0.03	0.01	0.97
ElG.electricity generation from fossil fuel	21	1.00	0.95	0.05	0.30	0.33	0.37
ElG.electricity generation from renewable sources	21	1.00	1.00	0.05	0.05	0.00	0.94
ElG.renewable share in total final energy consumption	21	1.00	0.97	0.12	0.25	0.59	0.16
ElG.total electricity generation	21	1.00	0.97	0.02	0.30	0.10	0.59
ElG.total electricity generation capacity by source[BIO]	21	1.00	0.99	0.05	0.00	0.17	0.82
ElG.total electricity generation capacity by source[GAS]	21	1.00	0.90	0.02	0.01	0.08	0.91
ElG.total electricity generation capacity by source[HYDRO]	21	1.00	0.98	0.00	0.01	0.09	0.90
ElG.total electricity generation capacity by source[NUCLEAR]	21	1.00	0.99	0.00	0.02	0.18	0.81
ElG.total electricity generation capacity by source[OIL]	21	1.00	0.97	0.03	0.02	0.16	0.82
EmW.crops emissions	21	1.00	0.72	0.07	0.01	0.52	0.47
EmW.fossil fuel emissions	21	1.00	0.90	0.04	0.09	0.14	0.77
EmW.industrial production emissions	21	1.00	0.97	0.03	0.05	0.11	0.84
EmW.livestock emissions	21	1.00	0.00	0.06	0.17	0.06	0.77
EmW.net co2 emissions from land use change	20	0.95	1.00	0.15	0.77	0.07	0.16
EmW.non energy agriculture emissions	21	1.00	0.51	0.04	0.12	0.05	0.83
EmW.per capita ghg emissions	21	1.00	0.97	0.03	0.04	0.06	0.91
EmW.proportion of urban waste collected and disposed	9	0.43	0.01	0.20	0.40	0.12	0.47
EmW.total ghg emissions in co2 equivalent	21	1.00	0.95	0.03	0.04	0.08	0.88
EmW.total pm 25 emissions	21	1.00	0.98	0.08	0.31	0.25	0.44
EmW.total waste generation	11	0.52	0.69	0.07	0.06	0.05	0.89
Emp.average employment to adult population ratio	21	1.00	0.62	0.03	0.76	0.01	0.23
Emp.employment by sector[agr 1]	20	0.95	0.77	0.09	0.23	0.11	0.66
Emp.employment by sector[agr 2]	20	0.95	0.97	0.02	0.10	0.09	0.81
Emp.employment by sector[agr 3]	20	0.95	0.89	0.09	0.08	0.00	0.92
Emp.employment by sector[agr 4]	20	0.95	0.78	0.99	0.00	0.19	0.81
Emp.employment by sector[agr 5]	21	1.00	0.71	0.03	0.19	0.11	0.71
Emp.employment by sector[ind 1]	21	1.00	0.81	0.02	0.10	0.29	0.61
Emp.employment by sector[ser 1]	21	1.00	0.98	0.03	0.70	0.19	0.10
Emp.employment by sector[ser 2]	21	1.00	0.99	0.01	0.00	0.03	0.97
Emp.employment to adult population ratio[FEMALE]	21	1.00	0.94	0.02	0.52	0.06	0.42
Emp.employment to adult population ratio[MALE]	21	1.00	0.46	0.03	0.79	0.08	0.13
Emp.female share of employment in managerial positions	21	1.00	0.02	0.09	0.75	0.02	0.23
Emp.gender gap in employment to adult population ratio[FEMALE]	21	1.00	0.98	0.01	0.55	0.25	0.20

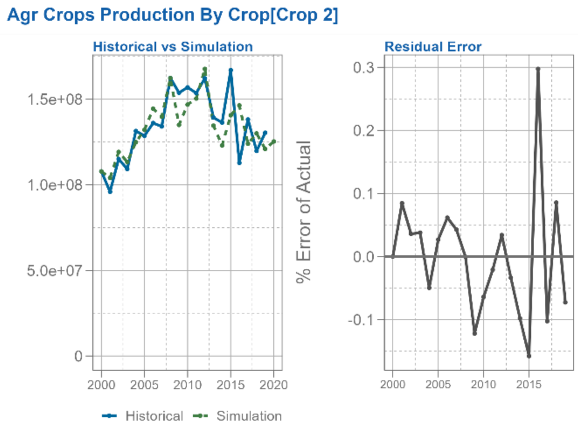
Variable	N	Data Coverage	R^2	RMSPE	Um	Us	Uc
Emp.gender gap in employment to adult population ratio[MALE]	21	1.00	0.98	0.01	0.52	0.27	0.20
Emp.public employment	21	1.00	0.99	0.01	0.00	0.03	0.97
Emp.total agriculture employment	21	1.00	0.94	0.05	0.37	0.20	0.43
Emp.total employment	21	1.00	0.98	0.02	0.60	0.17	0.23
Emp.total industry employment	21	1.00	0.81	0.02	0.10	0.29	0.61
Emp.total services employment	21	1.00	0.99	0.02	0.68	0.17	0.15
EnC.final energy consumption[BIO]	21	1.00	0.77	0.25	0.30	0.50	0.21
EnC.final energy consumption[COAL]	21	1.00	0.88	0.17	0.00	0.22	0.78
EnC.final energy consumption[ELE]	21	1.00	0.14	0.04	0.01	0.05	0.95
EnC.final energy consumption[GAS]	21	1.00	0.04	0.05	0.00	0.00	1.00
EnC.final energy consumption[HEAT]	21	1.00	0.01	0.10	0.00	0.42	0.58
EnC.final energy consumption[OIL]	21	1.00	0.53	0.04	0.03	0.00	0.96
EnC.total final energy consumption	21	1.00	0.18	0.03	0.11	0.07	0.82
EnC.total final energy consumption by sector[agr]	21	1.00	0.32	0.10	0.00	0.91	0.09
EnC.total final energy consumption by sector[ind]	21	1.00	0.65	0.04	0.01	0.17	0.83
EnC.total final energy consumption by sector[oth]	21	1.00	0.06	0.05	0.01	0.61	0.39
EnC.total final energy consumption by sector[res]	21	1.00	0.30	0.07	0.00	0.35	0.65
EnC.total final energy consumption by sector[ser]	21	1.00	0.67	0.05	0.00	0.04	0.96
EnC.total final energy consumption by sector[tra]	21	1.00	0.02	0.09	0.36	0.05	0.58
Fer.adolescent birth rate	21	1.00	0.97	0.05	0.17	0.10	0.73
Fer.births by gender[FEMALE]	21	1.00	0.24	0.06	0.07	0.17	0.76
Fer.births by gender[MALE]	21	1.00	0.24	0.06	0.07	0.17	0.76
Fer.total demand for family planning	21	1.00	0.70	0.01	0.16	0.17	0.67
Fer.total fertility rate	21	1.00	0.26	0.06	0.01	0.07	0.91
Fer.unmet need for family planning	21	1.00	0.90	0.04	0.24	0.09	0.67
Fin.foreign financing	21	1.00	1.00	0.03	0.15	0.16	0.69
Fin.gross international reserves	21	1.00	0.93	0.09	0.01	0.02	0.96
Fin.private domestic investment	21	1.00	0.94	0.07	0.43	0.00	0.57
Fin.private investment	21	1.00	0.93	0.07	0.36	0.08	0.56
Fin.public domestic debt	21	1.00	0.98	0.06	0.72	0.03	0.26
Fin.public foreign debt	21	1.00	0.99	0.04	0.10	0.25	0.65
Fin.total public debt	21	1.00	1.00	0.03	0.59	0.01	0.41
GDP.gdp mp deflator	21	1.00	1.00	0.00	0.69	0.17	0.00
GDP.gross national income	21	1.00	0.93	0.03	0.40	0.02	0.58
GDP.nominal gdp fc	21	1.00	0.98	0.03	0.35	0.06	0.59
GDP.real gdp fc	21	1.00	0.93	0.03	0.40	0.02	0.58
GDP.real gdp mp	21	1.00	0.93	0.03	0.40	0.02	0.58
GDP.total agriculture production	21	1.00	0.68	0.04	0.01	0.00	0.98
GDP.total industry production	21	1.00	0.71	0.03	0.03	0.17	0.80
GDP.total services production	21	1.00	0.93	0.03	0.44	0.06	0.50
Gnc.bribery incidence	9	0.43	0.03	0.12	0.92	0.07	0.01
Gov.government investment	21	1.00	0.98	0.03	0.07	0.01	0.92
Gov.government revenue	21	1.00	0.98	0.03	0.36	0.04	0.60
Gov.grants	21	1.00	0.99	0.03	0.25	0.19	0.56
Gov.revenue and grants	21	1.00	0.98	0.03	0.36	0.04	0.60
Gov.taxes on goods and services	21	1.00	0.98	0.03	0.36	0.04	0.60

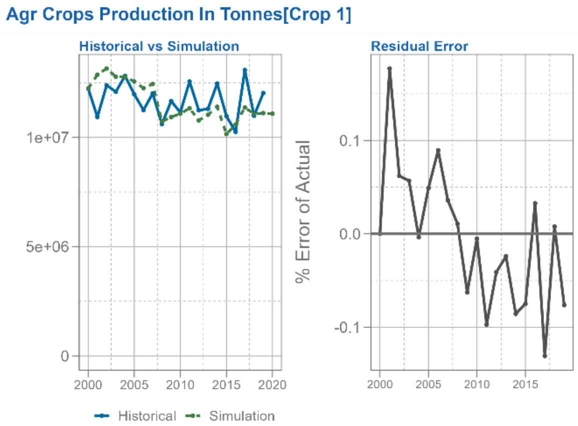
Variable	N	Data Coverage	R^2	RMSPE	Um	Us	Uc
Gov.taxes on international trade	21	1.00	0.92	0.07	0.14	0.00	0.86
Hhs.disposable income	21	1.00	0.97	0.15	0.96	0.01	0.04
Hhs.households revenue	21	1.00	0.98	0.08	0.89	0.00	0.11
Hhs.private consumption	21	1.00	0.87	0.24	0.93	0.01	0.05
Hhs.private current transfers	21	1.00	1.00	0.03	0.42	0.11	0.47
Hhs.private factor income	21	1.00	0.99	0.03	0.46	0.01	0.53
Hhs.private saving	21	1.00	0.96	0.06	0.47	0.00	0.53
Hlt.average access to basic health care	14	0.67	0.54	0.01	0.56	0.00	0.44
Hlt.pm 25 mean annual exposure	20	0.95	0.42	0.15	0.14	0.00	0.86
Hlt.proportion of population exposed to pm 25 levels exceeding WHO guideline	10	0.48	0.65	0.02	0.18	0.35	0.47
Ifr.infrastructure[paved]	21	1.00	0.99	0.00	0.31	0.04	0.65
Ifr.infrastructure[rail]	21	1.00	0.81	0.01	0.01	0.12	0.86
Ifr.infrastructure[unpaved]	21	1.00	0.94	0.00	0.00	0.46	0.54
Ifr.rural access index	21	1.00		0.00			
Inc.gini coefficient	18	0.86	0.12	0.11	0.70	0.00	0.29
Inc.income share by quintile[Q1]	21	1.00	0.47	0.03	0.01	0.14	0.85
Inc.income share by quintile[Q2]	21	1.00	0.08	0.02	0.05	0.01	0.94
Inc.income share by quintile[Q3]	21	1.00	0.23	0.10	0.94	0.01	0.05
Inc.income share by quintile[Q4]	21	1.00	0.09	0.05	0.28	0.12	0.60
Inc.income share by quintile[Q5]	21	1.00	0.28	0.05	0.36	0.09	0.55
Ind.industry production[ind 1]	21	1.00	0.71	0.03	0.03	0.17	0.80
Inv.investment	21	1.00	0.95	0.06	0.39	0.06	0.54
Lnd.agriculture land[agr 1]	20	0.95	0.01	0.03	0.26	0.10	0.64
Lnd.agriculture land[agr 2]	20	0.95	0.88	0.02	0.05	0.61	0.33
Lnd.forest land	20	0.95	0.80	0.01	0.02	0.19	0.79
Lnd.harvested area[crop 1]	20	0.95	0.85	0.03	0.25	0.20	0.55
Lnd.harvested area[crop 2]	20	0.95	0.72	0.03	0.27	0.05	0.68
Lnd.other land	20	0.95	0.06	0.08	0.77	0.03	0.20
Lnd.terrestrial areas formally protected	21	1.00	0.63	0.02	0.32	0.02	0.66
Mat.domestic material consumption	21	1.00	0.80	0.03	0.18	0.01	0.81
Mat.minerals and metals consumption[metal ores]	21	1.00	0.95	0.11	0.76	0.07	0.17
Mat.minerals and metals consumption[non metallic minerals]	21	1.00	0.84	0.06	0.61	0.00	0.38
Mat.minerals and metals extraction[non metallic minerals]	21	1.00	0.94	0.03	0.04	0.03	0.93
Mat.pc material footprint	18	0.86	0.01	0.05	0.00	0.43	0.57
Mat.total biomass extraction	20	0.95	0.24	0.05	0.09	0.03	0.88
Mat.total material extraction	20	0.95	0.90	0.03	0.02	0.28	0.71
Mat.total minerals and metal ores consumption	21	1.00	0.82	0.07	0.70	0.00	0.30
Mat.total minerals and metal ores extraction	21	1.00	0.94	0.03	0.04	0.03	0.93
Mor.average life expectancy	21	1.00	0.96	0.00	0.30	0.04	0.66
Mor.infant mortality rate	21	1.00	0.76	0.09	0.13	0.34	0.52
Mor.life expectancy[FEMALE]	21	1.00	0.94	0.00	0.31	0.04	0.65
Mor.life expectancy[MALE]	21	1.00	0.97	0.00	0.25	0.06	0.70
Mor.maternal mortality ratio	18	0.86	0.88	0.29	0.94	0.05	0.01
Mor.neonatal mortality rate	21	1.00	0.87	0.41	0.98	0.01	0.01

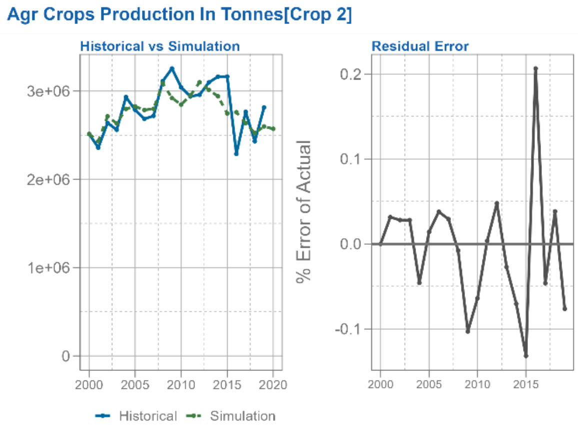
Variable	N	Data Coverage	R^2	RMSPE	Um	Us	Uc
Mor.under five mortality rate	21	1.00	0.83	0.07	0.05	0.21	0.74
PES.energy intensity level of primary energy	21	1.00	0.96	0.03	0.37	0.00	0.62
PES.primary energy production[BIO]	21	1.00	0.62	0.43	0.00	0.82	0.18
PES.primary energy production[HYDRO]	21	1.00	1.00	0.00	0.01	0.03	0.96
PES.primary energy production[NUCLEAR]	21	1.00	1.00	0.00			
PES.primary energy production[SOLAR]	21	1.00	1.00		0.04	0.06	0.90
PES.primary energy production[WIND]	21	1.00	1.00	0.21	0.01	0.03	0.96
PES.total energy transformation and losses	21	1.00	0.98	0.04	0.65	0.10	0.25
PES.total primary energy net import	21	1.00	0.85	0.03	0.00	0.40	0.60
PES.total primary energy production	21	1.00	0.77	0.05	0.00	0.03	0.97
PES.total primary energy supply	21	1.00	0.74	0.02	0.00	0.00	1.00
Pop.population by gender[FEMALE]	21	1.00	1.00	0.00	0.53	0.06	0.41
Pop.population by gender[MALE]	21	1.00	1.00	0.00	0.14	0.67	0.19
Pop.total population	21	1.00	1.00	0.00	0.15	0.44	0.41
Ser.public services production	21	1.00	0.97	0.02	0.34	0.06	0.59
Ser.services production[ser 1]	21	1.00	0.92	0.04	0.45	0.05	0.49
Sln.crop nutrient uptake[N]	19	0.90	0.05	0.09	0.00	0.16	0.84
Sln.fertilizer consumption[N]	20	0.95	0.86	0.03	0.27	0.18	0.55
Sln.nutrient from manure application[N]	19	0.90	0.85	0.03	0.01	0.08	0.90
Sln.soil primary nitrogen balance	19	0.90	0.75	0.03	0.17	0.05	0.78
Veh.total motor fuel consumption	21	1.00	0.38	0.06	0.18	0.03	0.79
Veh.total vehicles by type[commercial, ic]	21	1.00	0.95	0.03	0.06	0.28	0.66
Veh.total vehicles by type[passenger, ic]	21	1.00	0.97	0.02	0.29	0.14	0.57
WaS.Access to safely managed sanitation facility[rural]	21	1.00	0.25	0.06	0.21	0.17	0.62
WaS.Access to safely managed sanitation facility[urban]	21	1.00	0.39	0.06	0.16	0.02	0.82
WaS.Access to safely managed water source[rural]	21	1.00	0.29	0.01	0.00	0.68	0.32
WaS.Access to safely managed water source[urban]	21	1.00	0.24	0.01	0.05	0.77	0.18
WaS.average access to safely managed sanitation facility	21	1.00	0.39	0.06	0.16	0.01	0.82
WaS.average access to safely managed water source	21	1.00	0.24	0.01	0.05	0.77	0.18
WaS.total renewable water resources	20	0.95		0.10	0.70	0.30	
WaW.agriculture water withdrawal	20	0.95	0.97	0.02	0.00	0.22	0.78
WaW.domestic and municipal water withdrawal	20	0.95	0.04	0.05	0.43	0.13	0.44
WaW.harvested area irrigated	20	0.95	0.96	0.03	0.24	0.08	0.68
WaW.industry water withdrawal	20	0.95	0.94	0.06	0.09	0.00	0.91
WaW.irrigation water withdrawal	20	0.95		0.03	0.26	0.74	
WaW.livestock water withdrawal	20	0.95	0.97	0.06	0.15	0.01	0.84
WaW.total water withdrawal	20	0.95	0.94	0.05	0.16	0.01	0.83

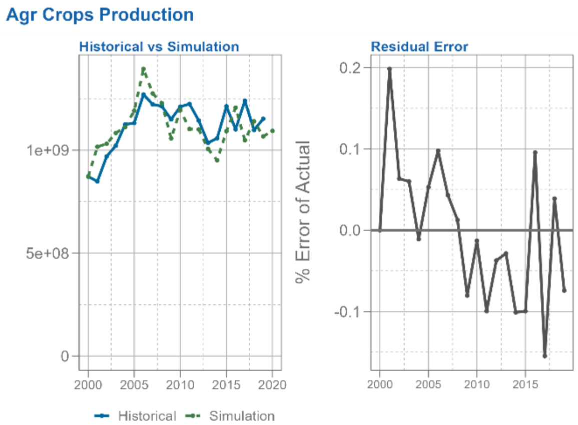
Annexe 2.2 - Historical behaviour reproduction figures

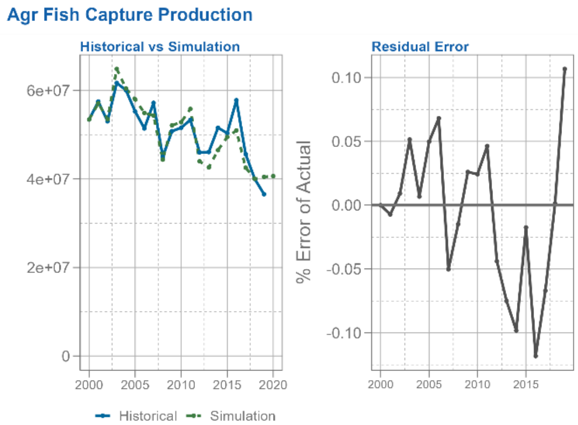




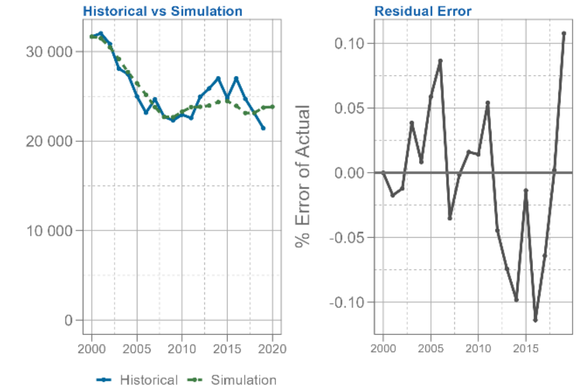




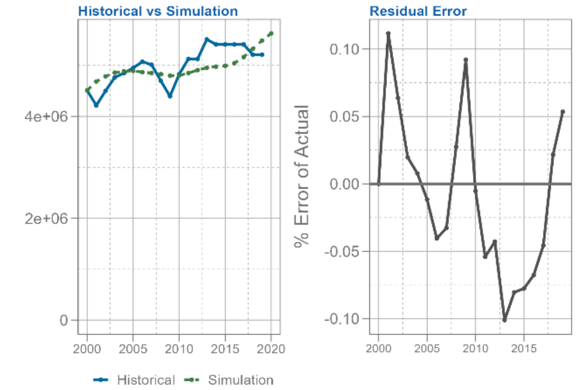




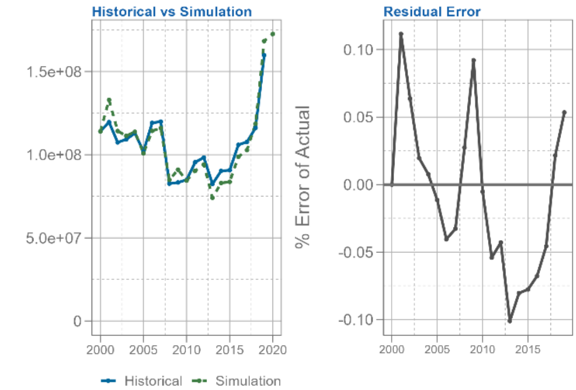
Agr Fish Production In Tonnes



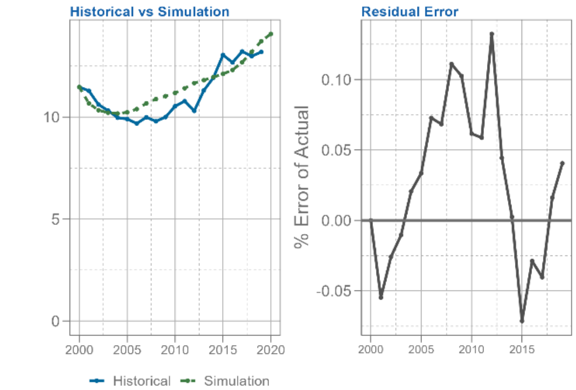
Agr Forestry Production In Cubic Meters By Wood Type[Wood 1]



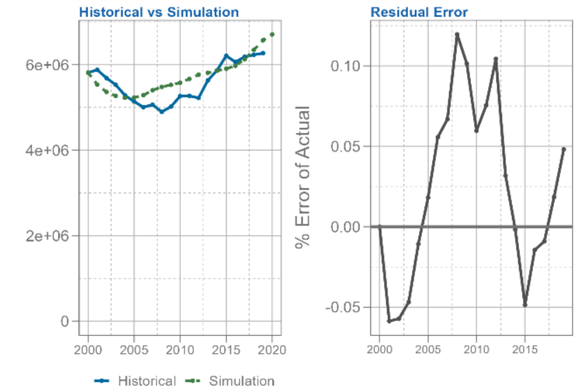
Agr Forestry Production



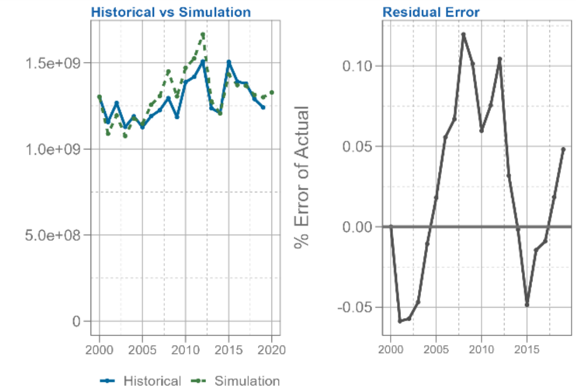
Agr Livestock Production In Tonnes Per Hectare[Animal 1]



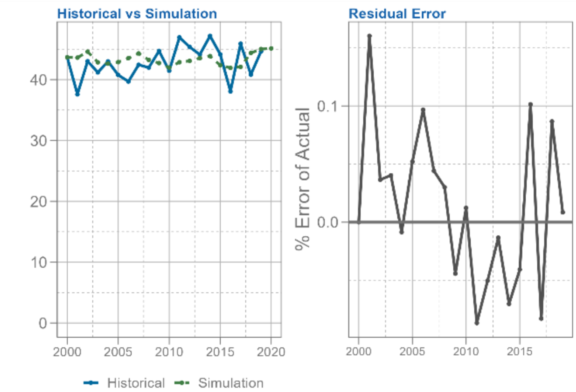
Agr Livestock Production In Tonnes[Animal 1]



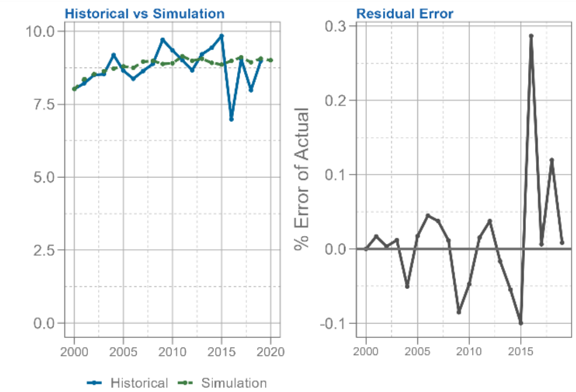
Agr Livestock Production



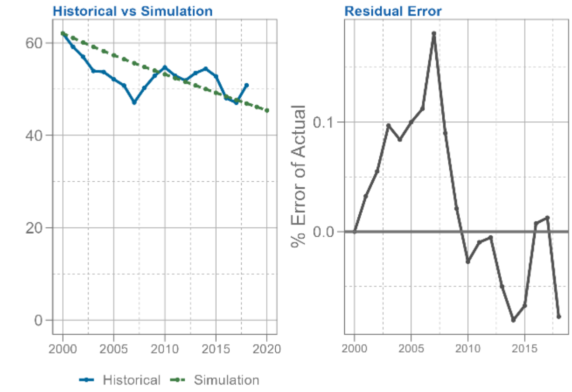
Agr Yield[Crop 1]



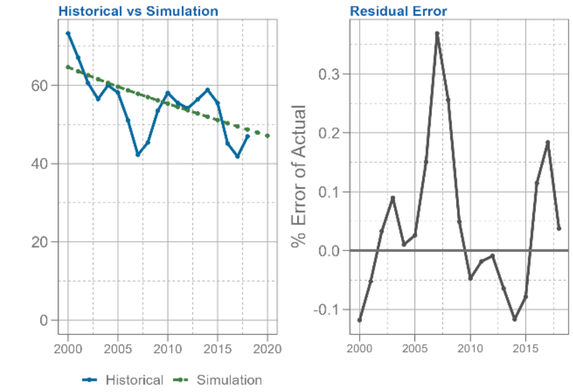
Agr Yield[Crop 2]



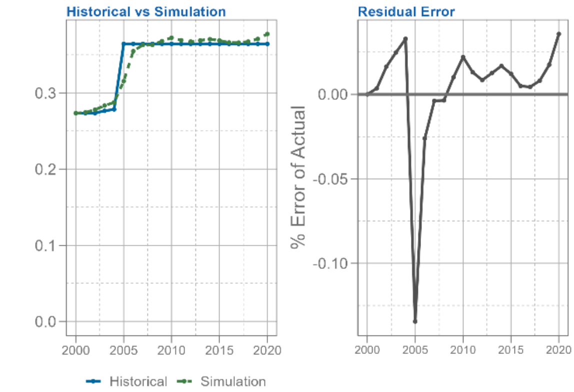
Bdv Fish Resources Availability Share



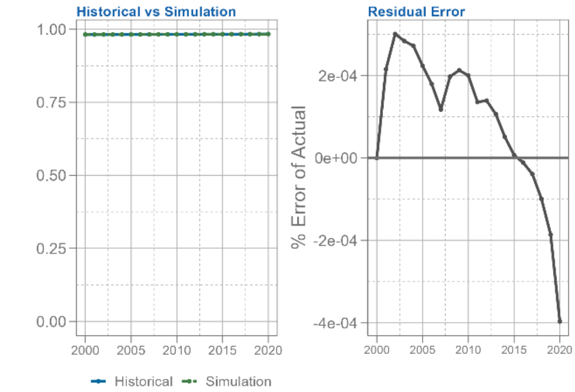
Bdv Proportion Of Fish Stocks Sustainably Exploited



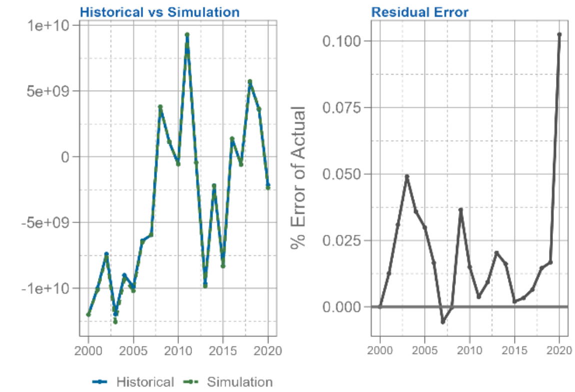
Bdv Proportion Of Territorial Waters Formally Protected



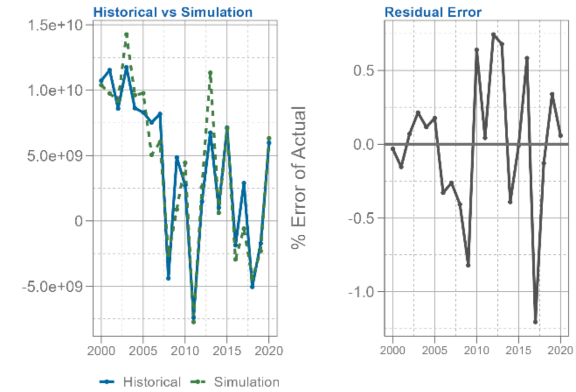
Bdv Red List Index



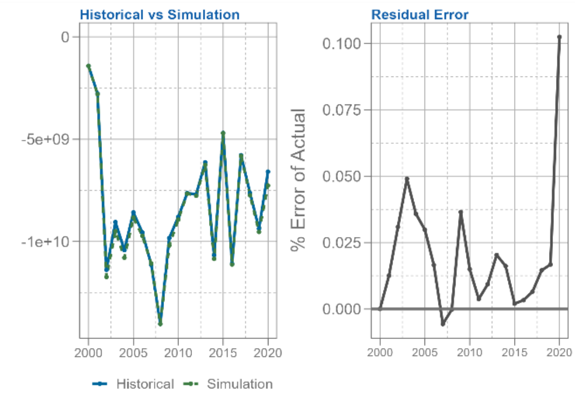
Bop Capital And Financial Account Balance



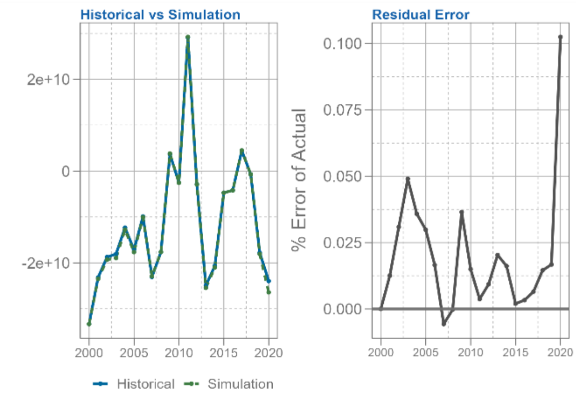
Bop Current Account Balance



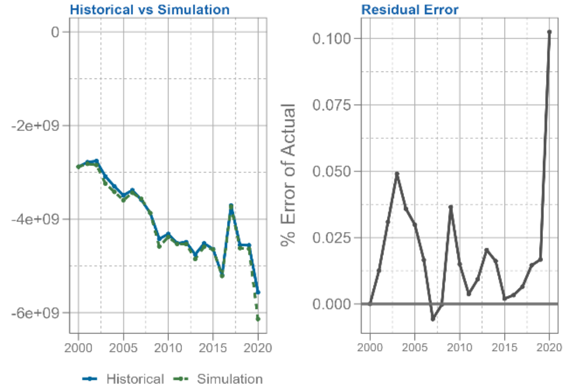
Bop Net Current Transfers



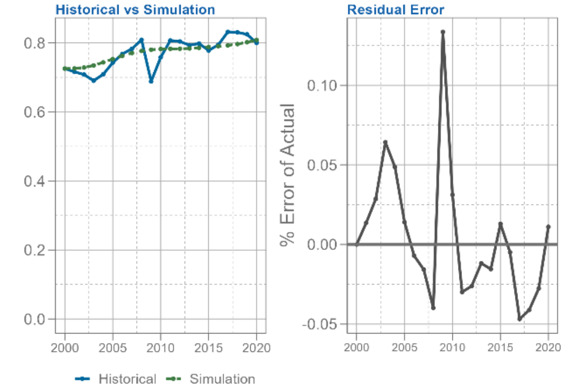
Bop Private Capital And Financial Account



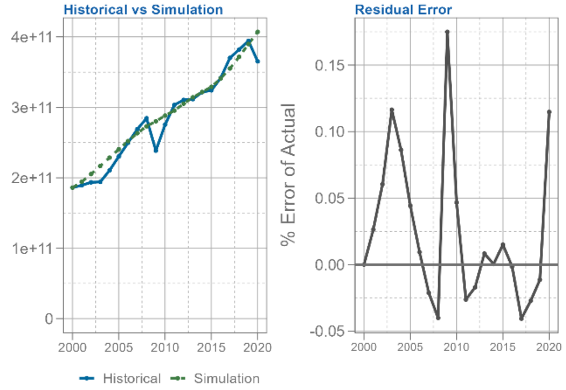
Bop Public Current Transfers



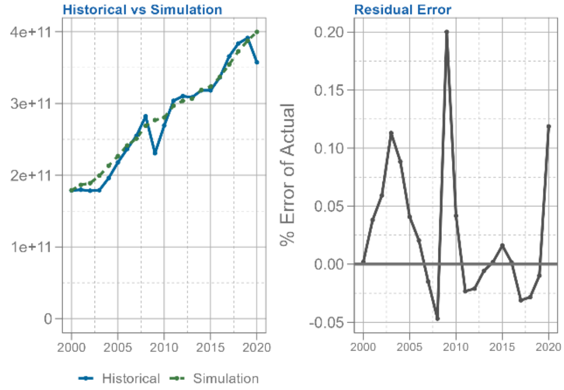
Bop Total Export Share Of Gdp



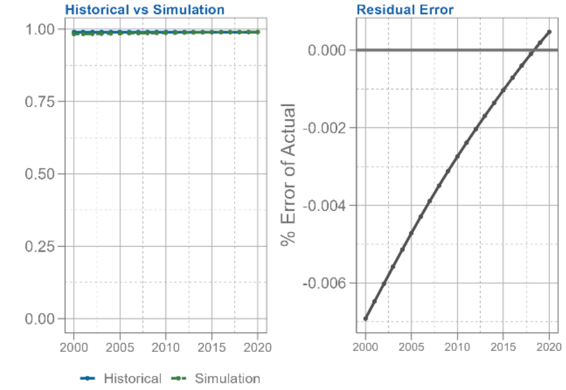
Bop Total Export



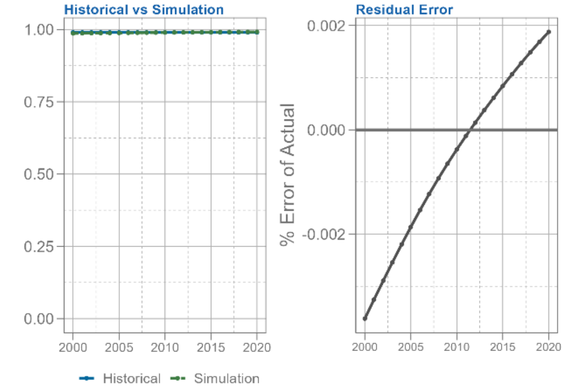
Bop Total Import



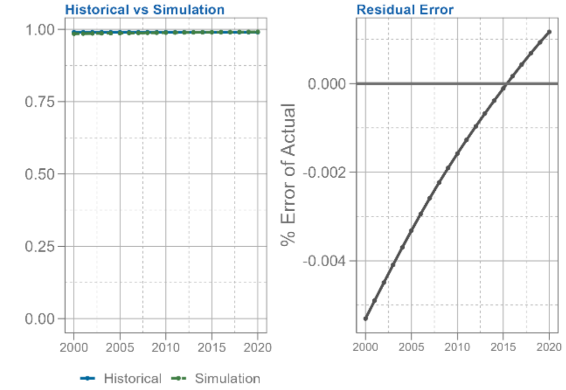
Edu Adult Literacy Rate[Female]



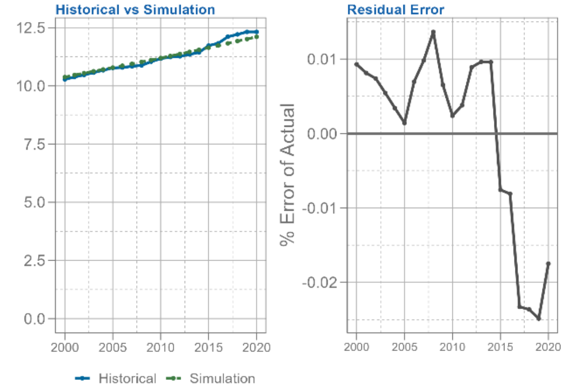
Edu Adult Literacy Rate[Male]



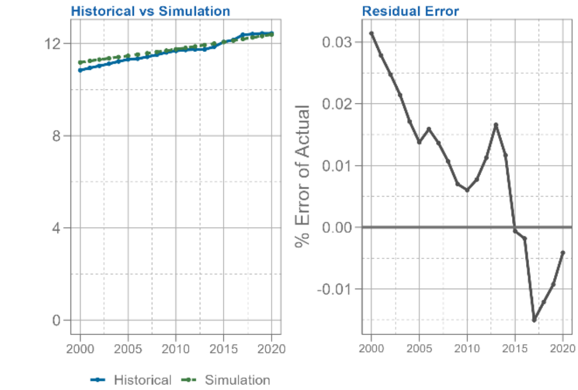
Edu Average Adult Literacy Rate



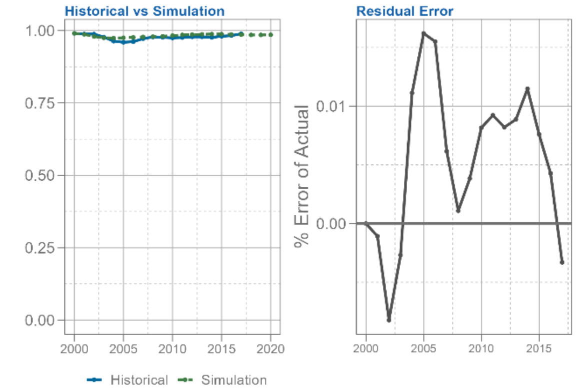
Edu Average Years Of Schooling[Female]



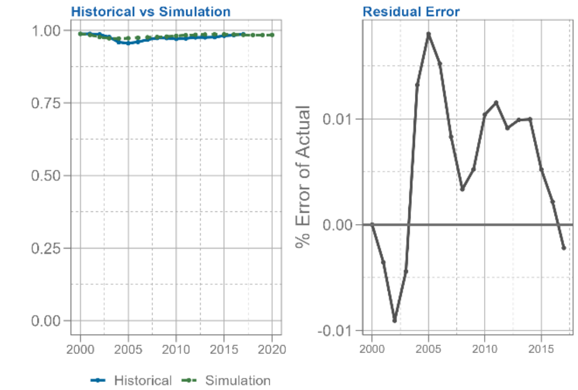
Edu Average Years Of Schooling[Male]



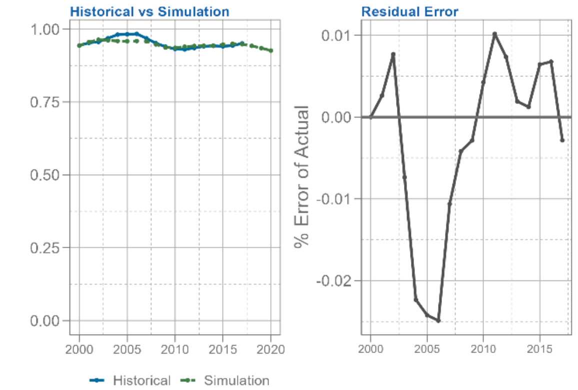
Edu Primary Net Enrollment Rate[Female]



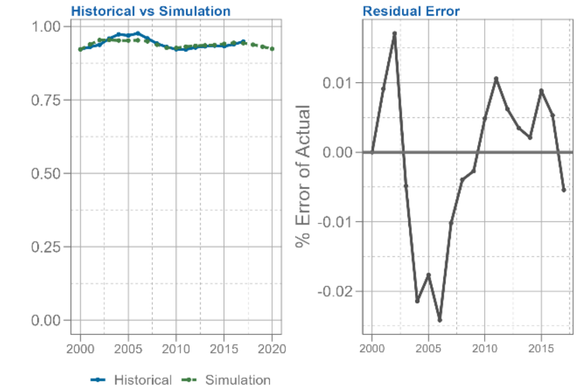
Edu Primary Net Enrollment Rate[Male]



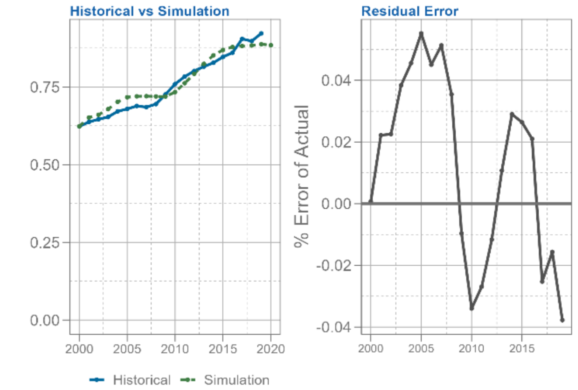
Edu Secondary Net Enrollment Rate[Female]



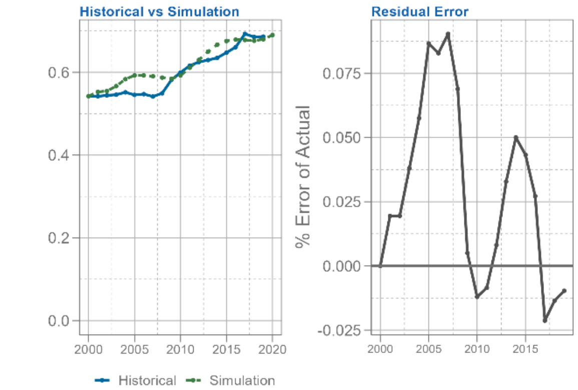
Edu Secondary Net Enrollment Rate[Male]



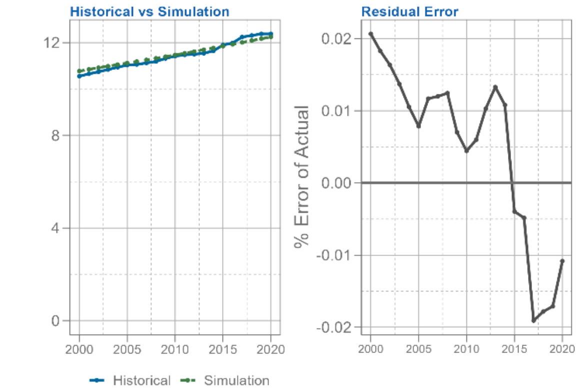
Edu Tertiary Gross Enrollment Rate[Female]



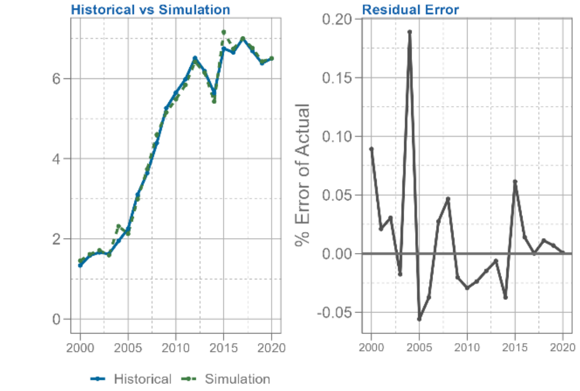
Edu Tertiary Gross Enrollment Rate[Male]



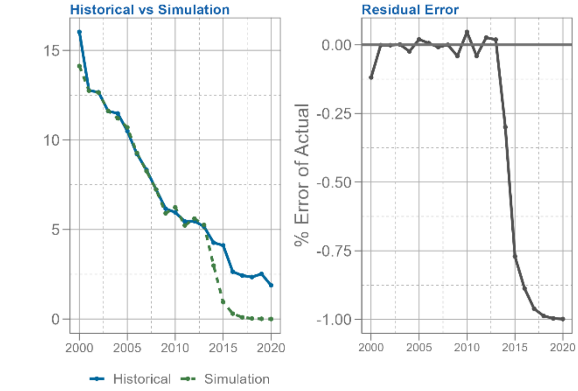
Edu Total Average Years Of Schooling



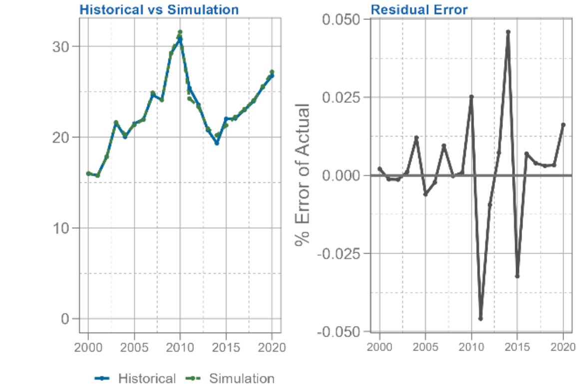
Elg Electricity Generation By Source[Bio]



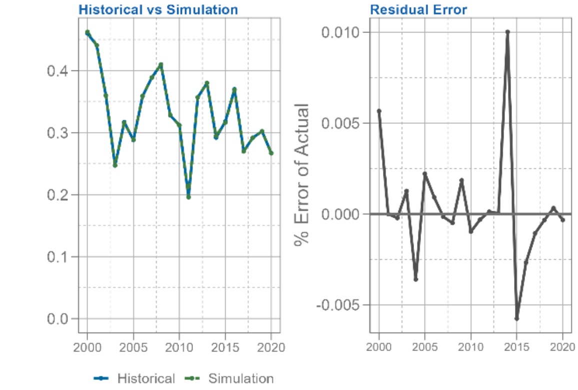
Elg Electricity Generation By Source[Coal]



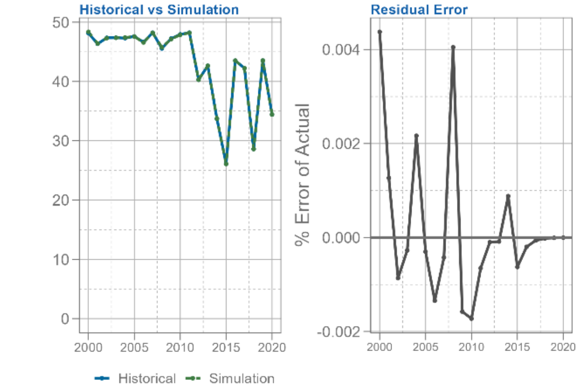
Elg Electricity Generation By Source[Gas]



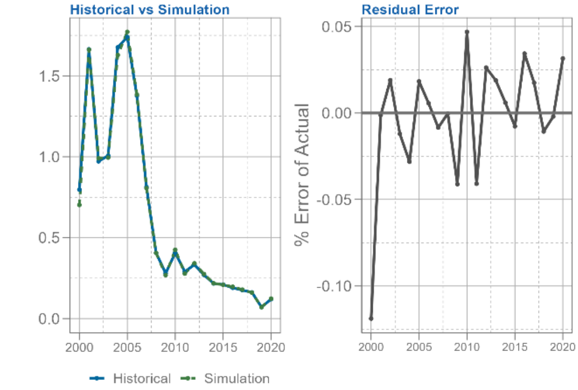
Elg Electricity Generation By Source[Hydro]



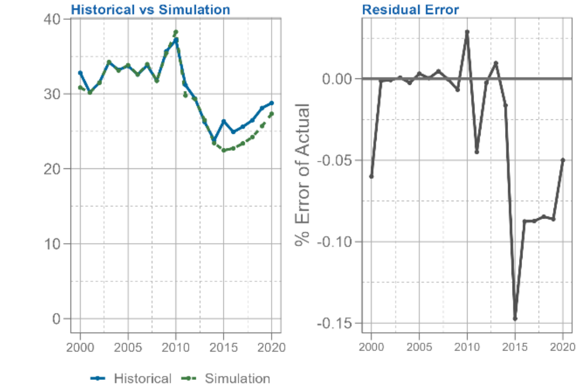
Elg Electricity Generation By Source[Nuclear]



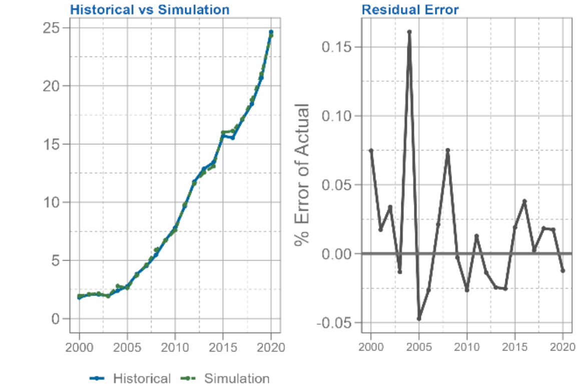
Elg Electricity Generation By Source[Oil]



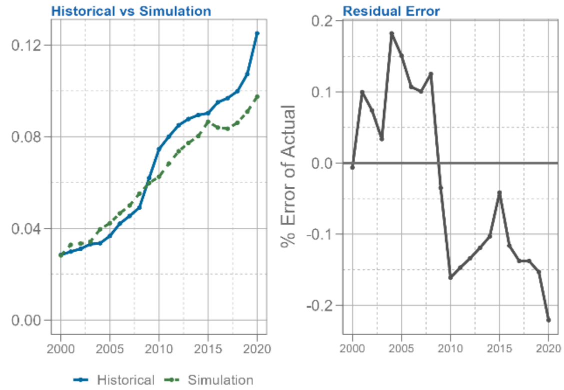
Elg Electricity Generation From Fossil Fuel



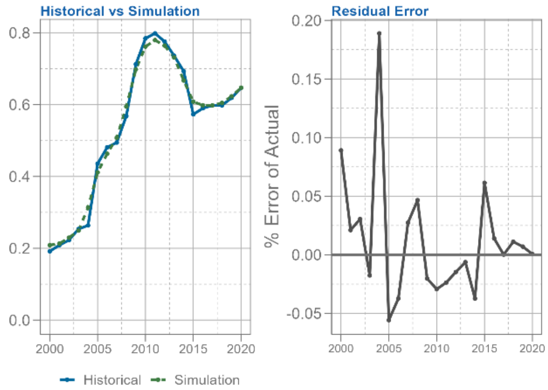
Elg Electricity Generation From Renewable Sources



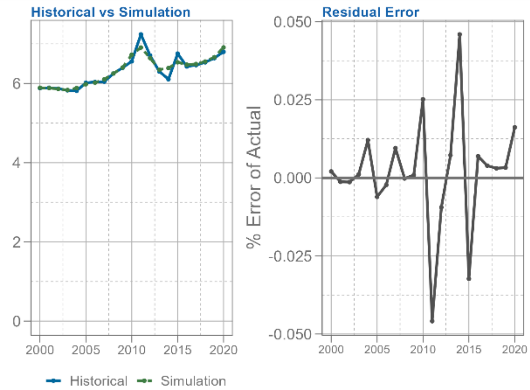
Elg Renewable Share In Total Final Energy Consumption



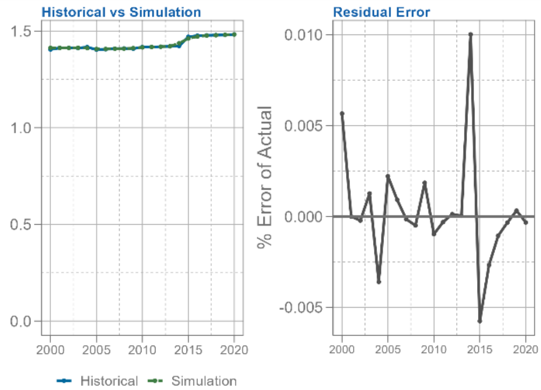
Elg Total Electricity Generation Capacity By Source[Bio]



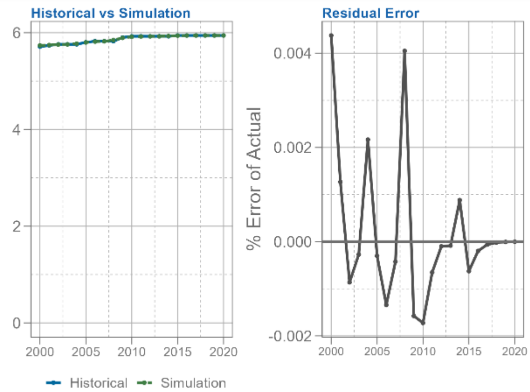
Elg Total Electricity Generation Capacity By Source[Gas]



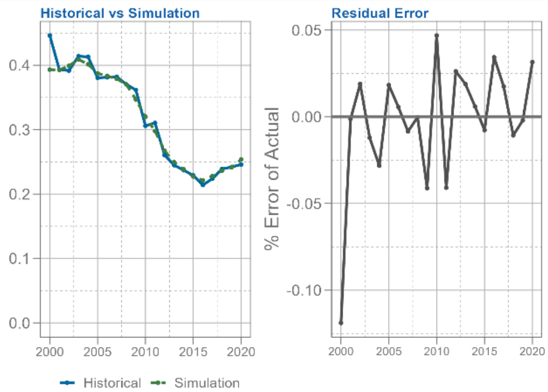
Elg Total Electricity Generation Capacity By Source[Hydro]



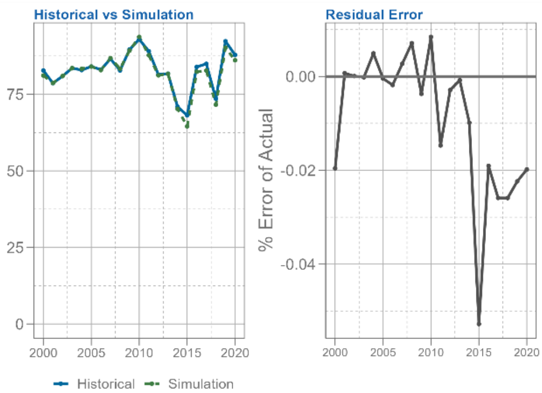
Elg Total Electricity Generation Capacity By Source[Nuclear]



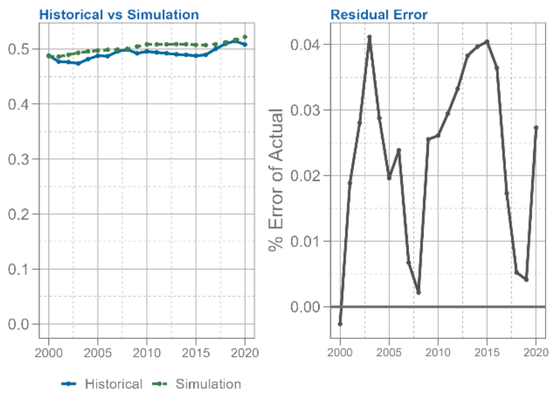
Elg Total Electricity Generation Capacity By Source[Oil]



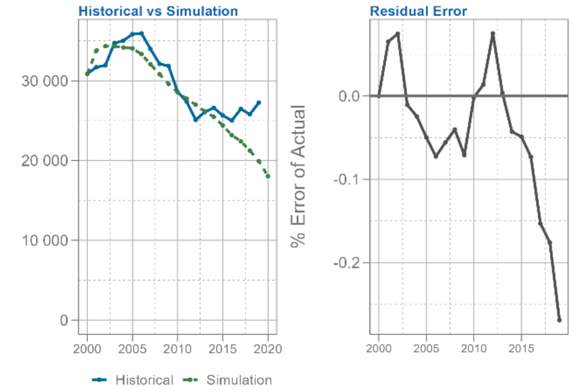
Elg Total Electricity Generation



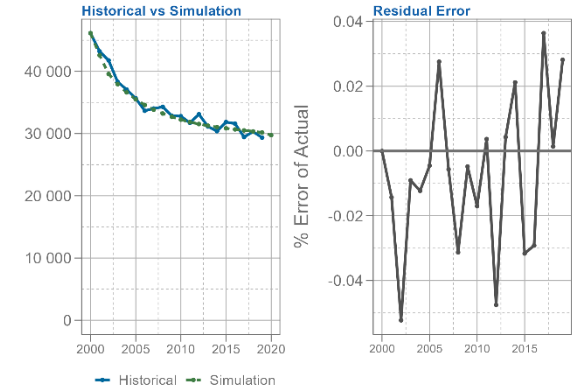
Emp Average Employment To Adult Population Ratio



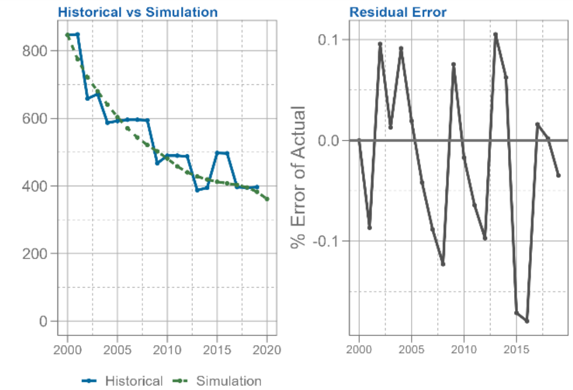
Emp Employment By Sector[Agr 1]



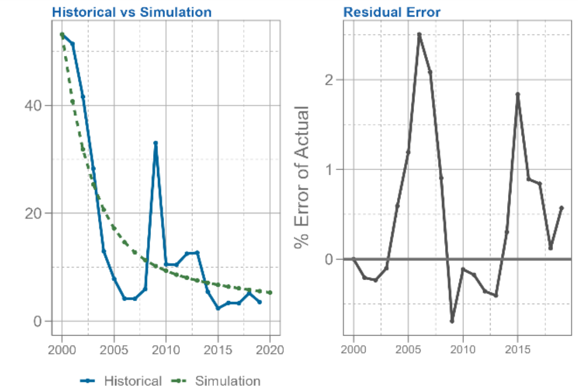
Emp Employment By Sector[Agr 2]



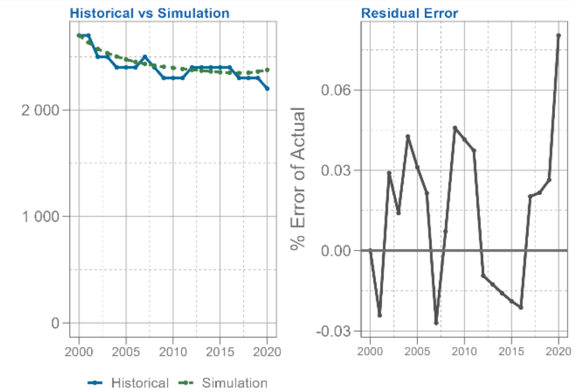
Emp Employment By Sector[Agr 3]



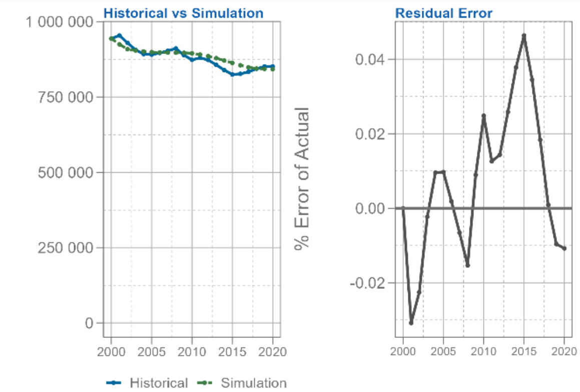
Emp Employment By Sector[Agr 4]



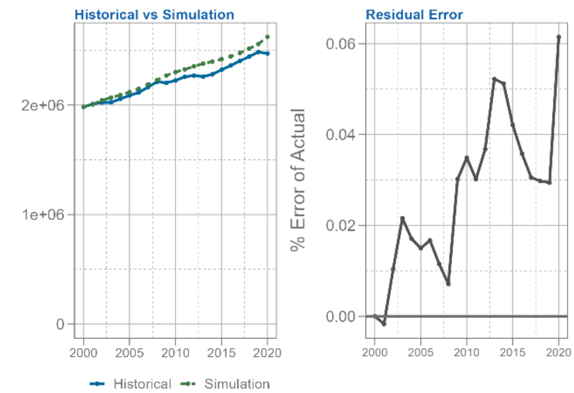
Emp Employment By Sector[Agr 5]



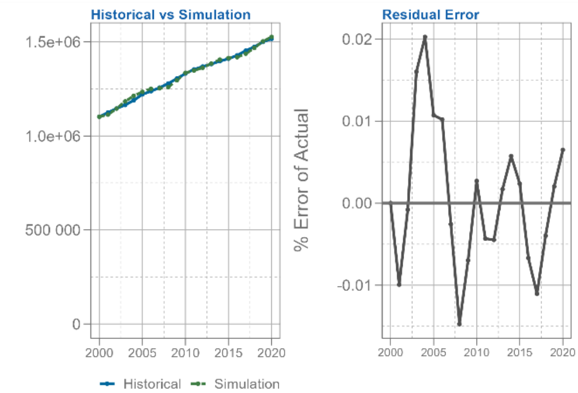
Emp Employment By Sector[Ind 1]



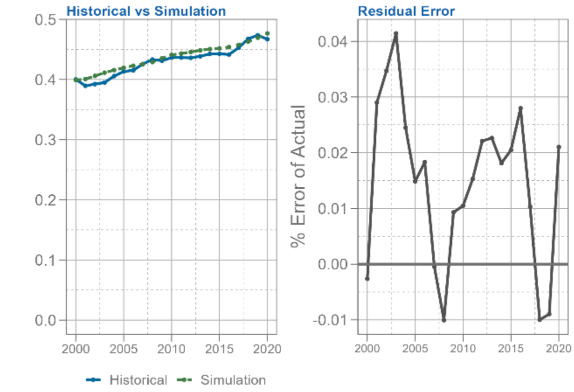
Emp Employment By Sector[Ser 1]



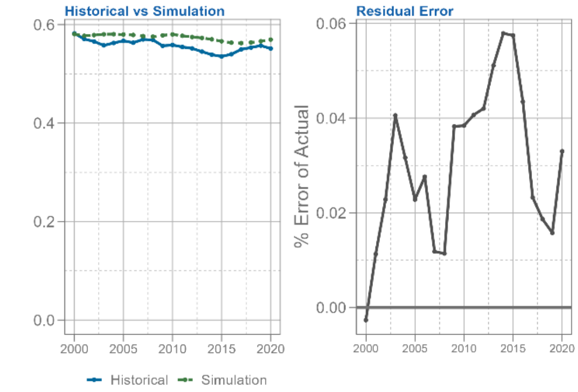
Emp Employment By Sector[Ser 2]



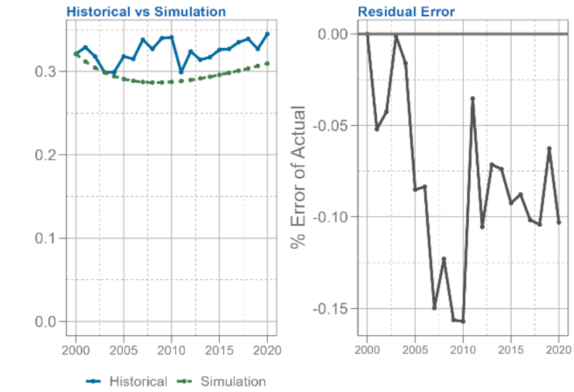
Emp Employment To Adult Population Ratio[Female]



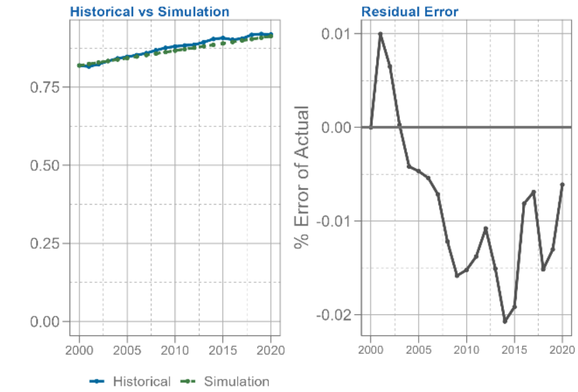
Emp Employment To Adult Population Ratio[Male]



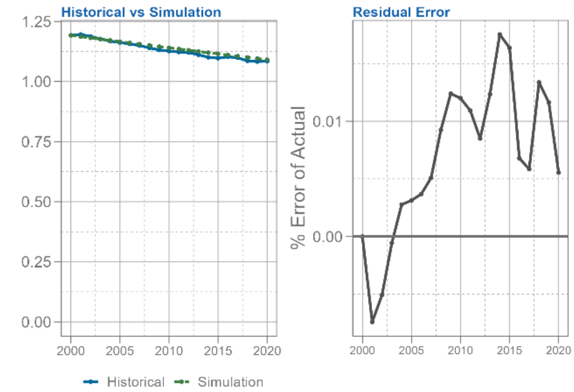
Emp Female Share Of Employment In Managerial Positions



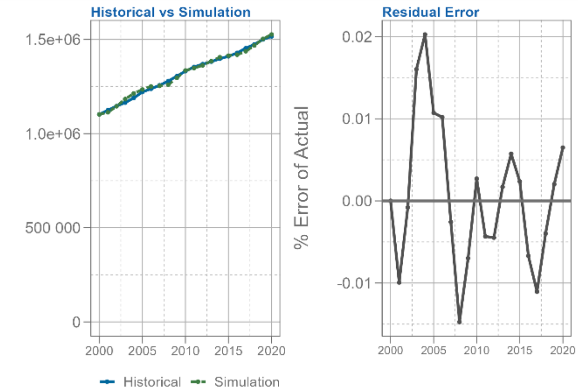
Emp Gender Gap In Employment To Adult Population Ratio[Female]



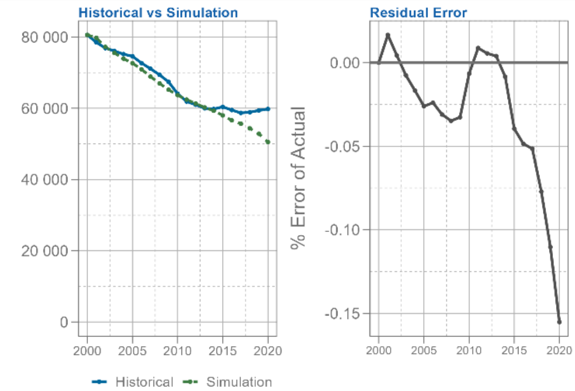
Emp Gender Gap In Employment To Adult Population Ratio[Male]



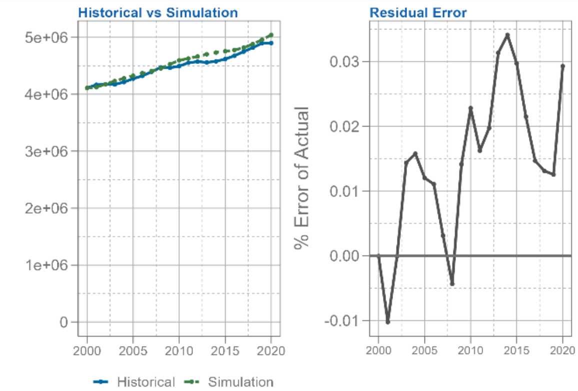
Emp Public Employment



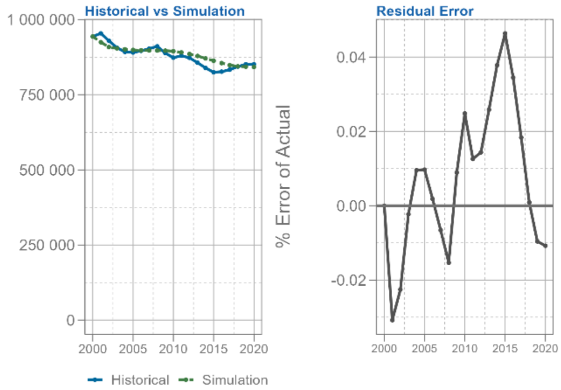
Emp Total Agriculture Employment



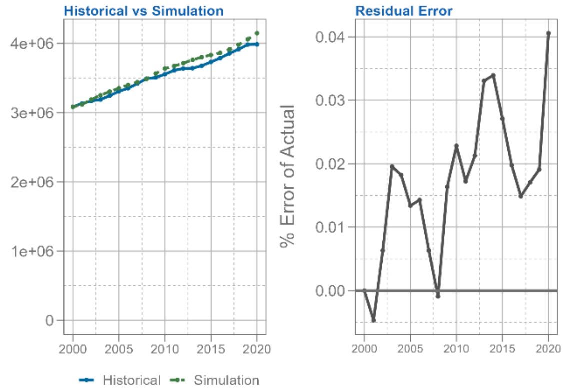
Emp Total Employment



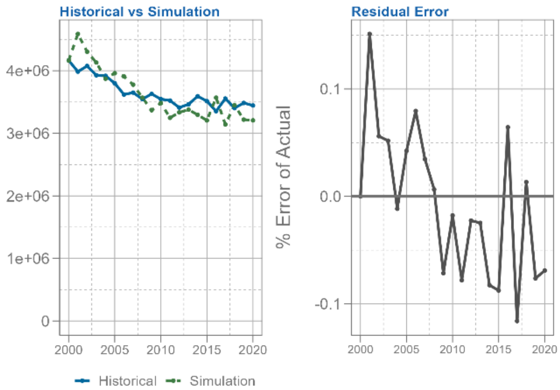
Emp Total Industry Employment



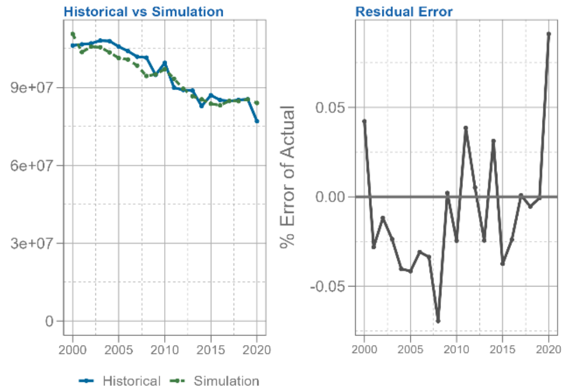
Emp Total Services Employment



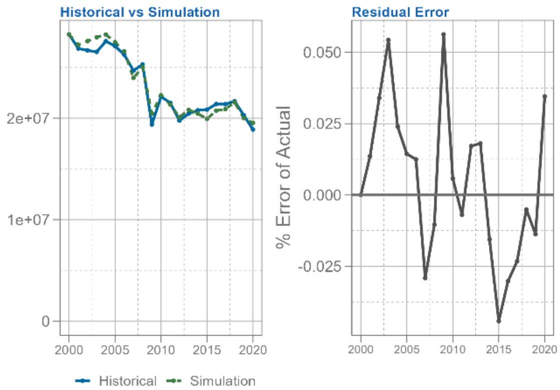
Emw Crops Emissions



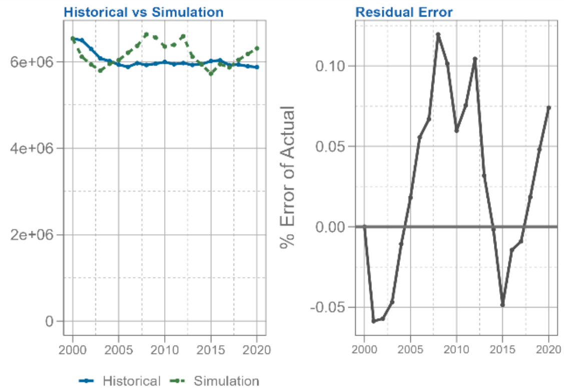
Emw Fossil Fuel Emissions



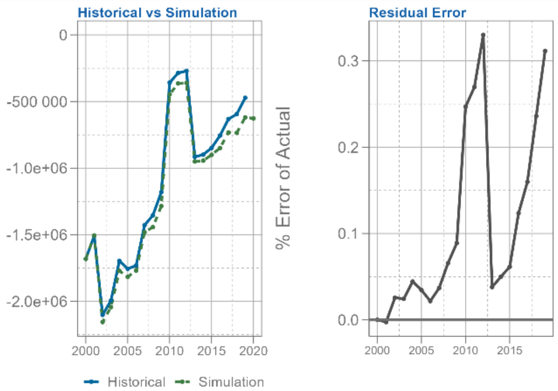
Emw Industrial Production Emissions



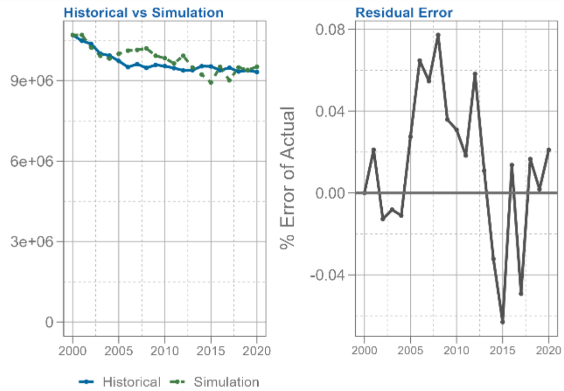
Emw Livestock Emissions



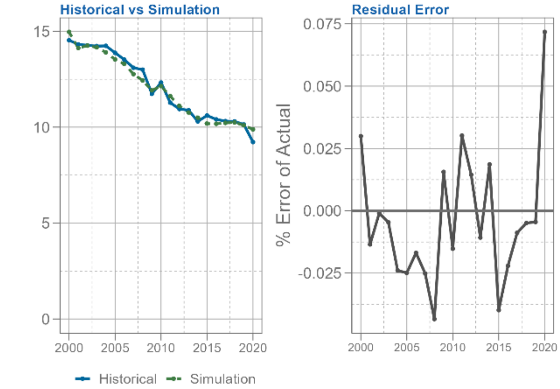
Emw Net Co2 Emissions From Land Use Change



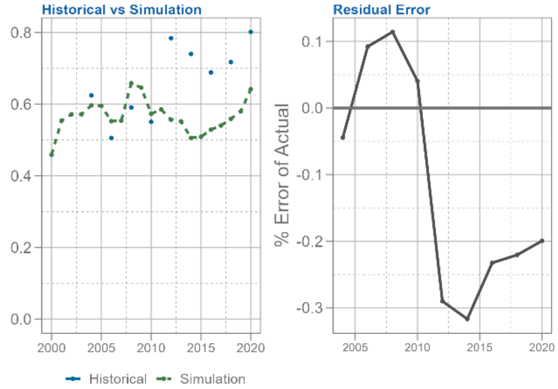
Emw Non Energy Agriculture Emissions



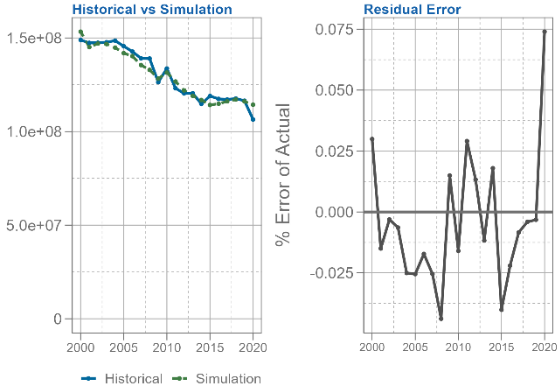
Emw Per Capita Ghg Emissions



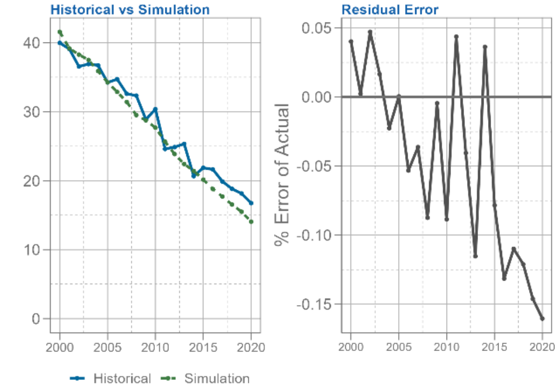
Emw Proportion Of Urban Waste Collected And Disposed



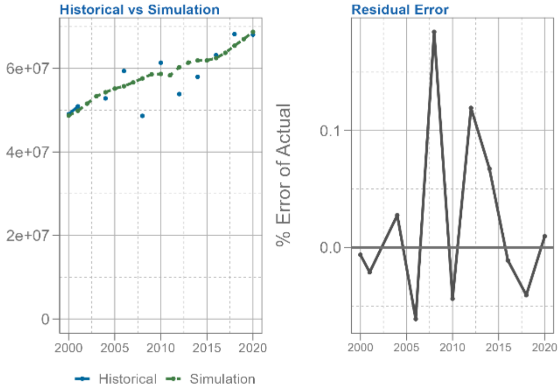
Emw Total Ghg Emissions In Co2 Equivalent



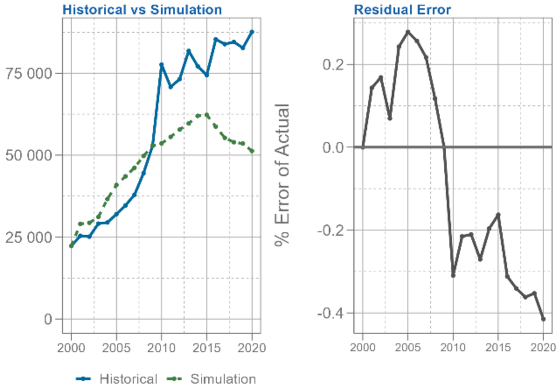
Emw Total Pm 25 Emissions



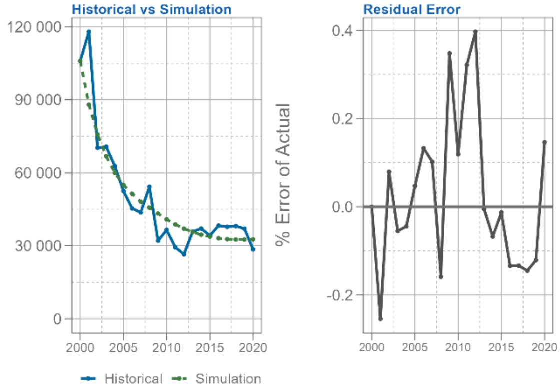
Emw Total Waste Generation



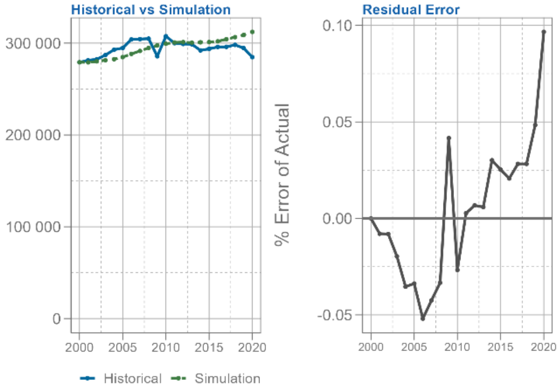
Enc Final Energy Consumption[Bio]



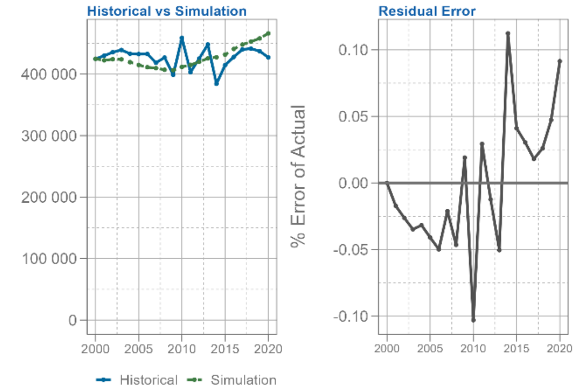
Enc Final Energy Consumption[Coal]



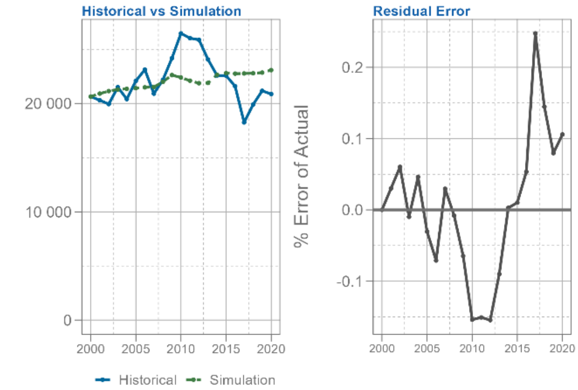
Enc Final Energy Consumption[Ele]



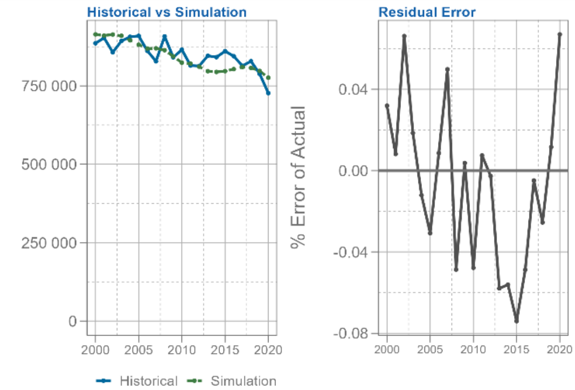
Enc Final Energy Consumption[Gas]



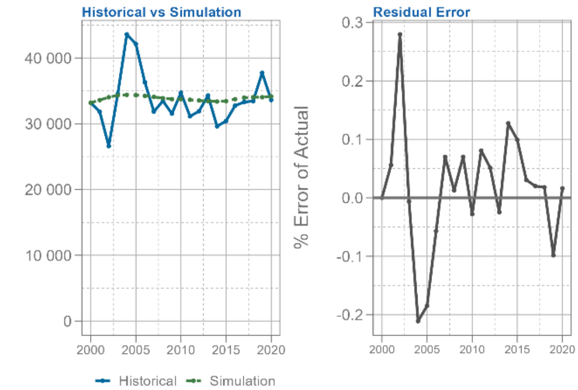
Enc Final Energy Consumption[Heat]



Enc Final Energy Consumption[Oil]



Enc Total Final Energy Consumption By Sector[Agr]



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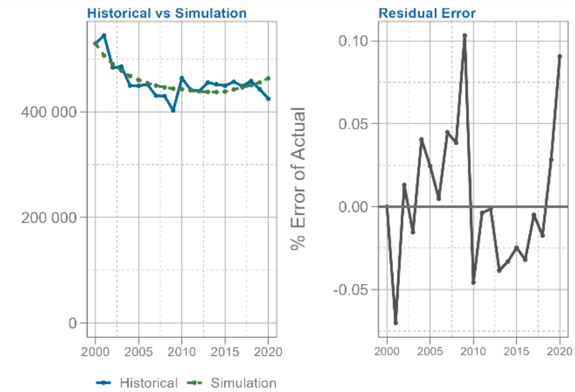
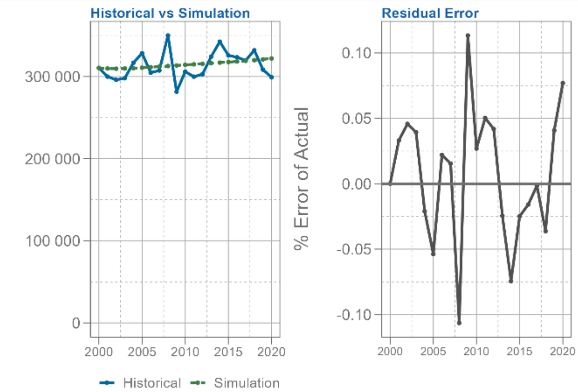
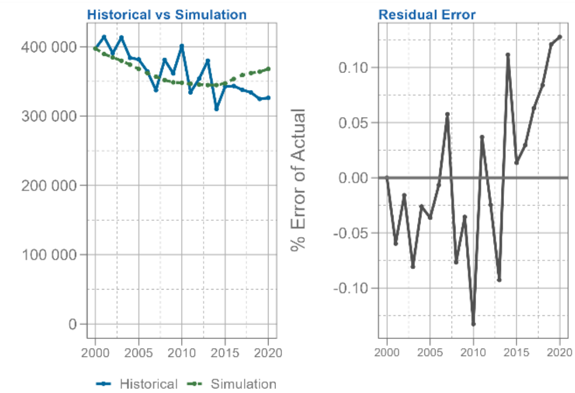


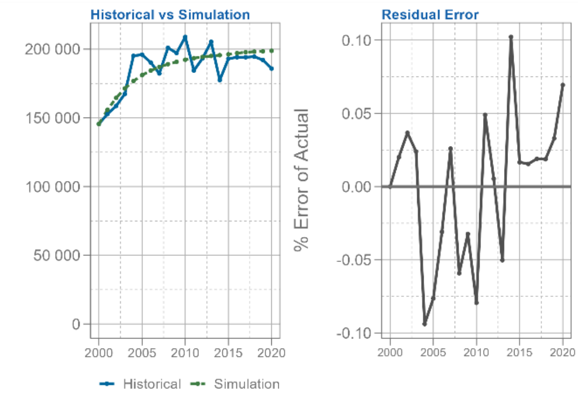
Enc Total Final Energy Consumption By Sector[Oth]



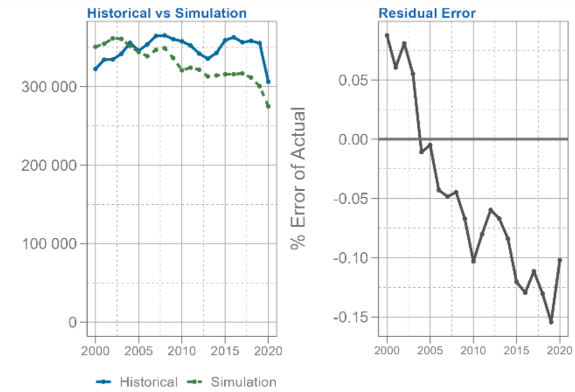
Enc Total Final Energy Consumption By Sector[Res]



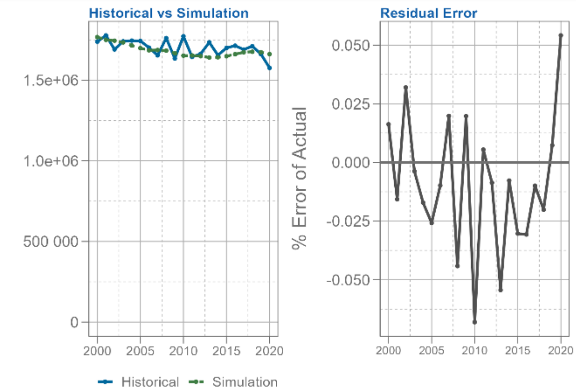
Enc Total Final Energy Consumption By Sector[Ser]



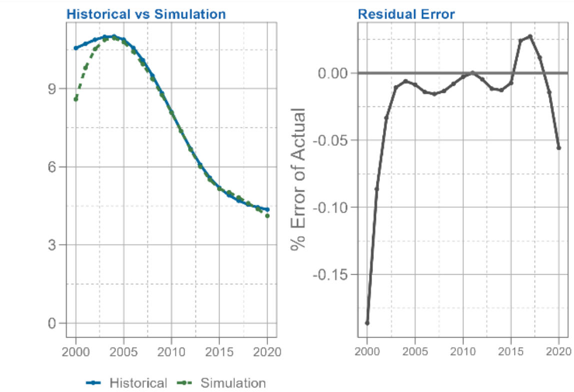
Enc Total Final Energy Consumption By Sector[Tra]



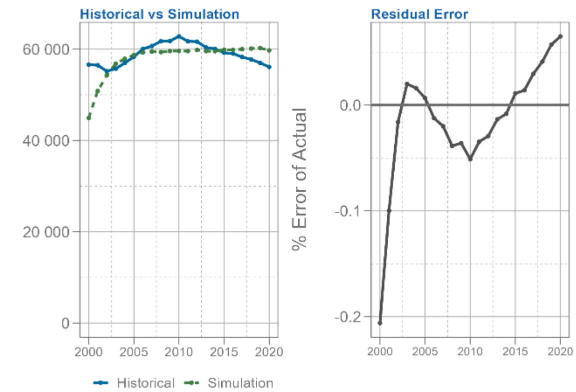
Enc Total Final Energy Consumption



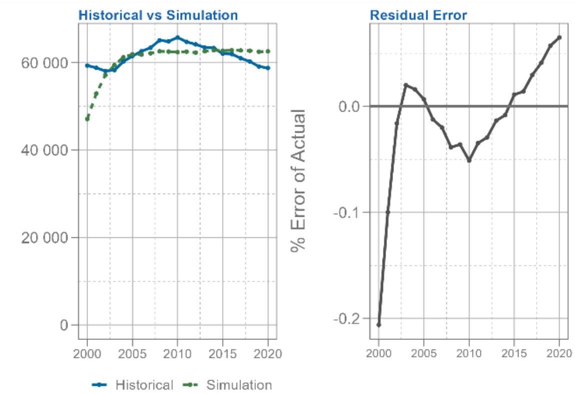
Fer Adolescent Birth Rate



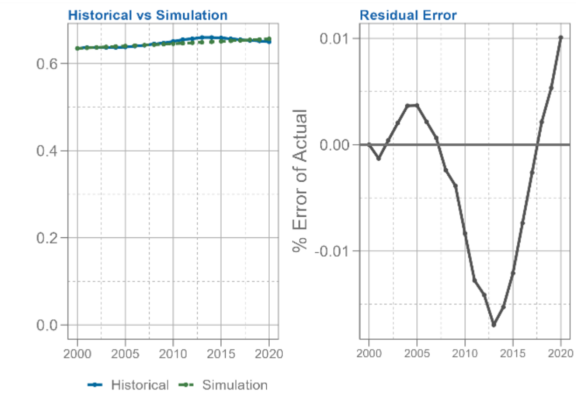
Fer Births By Gender[Female]



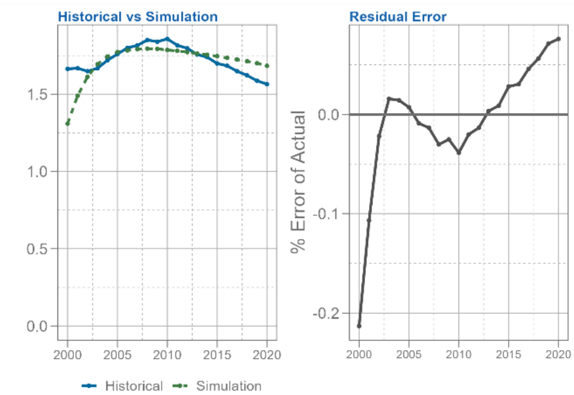
Fer Births By Gender[Male]



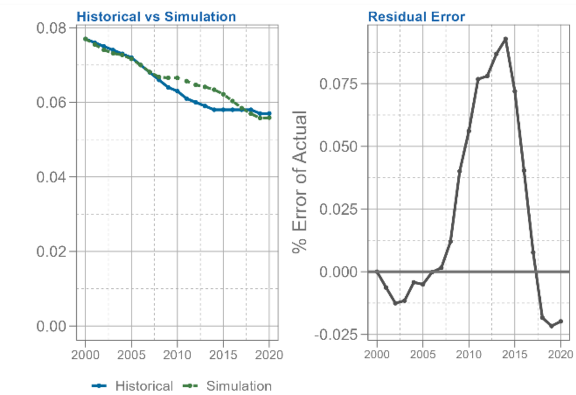
Fer Total Demand For Family Planning



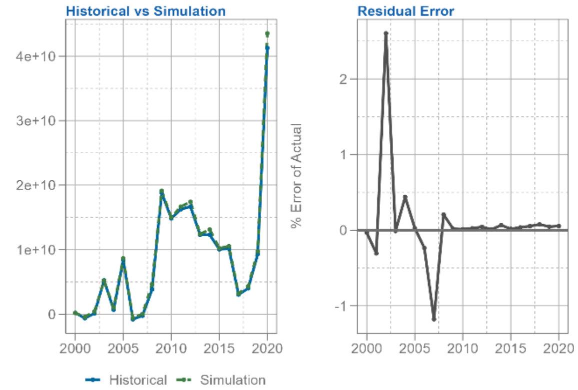
Fer Total Fertility Rate



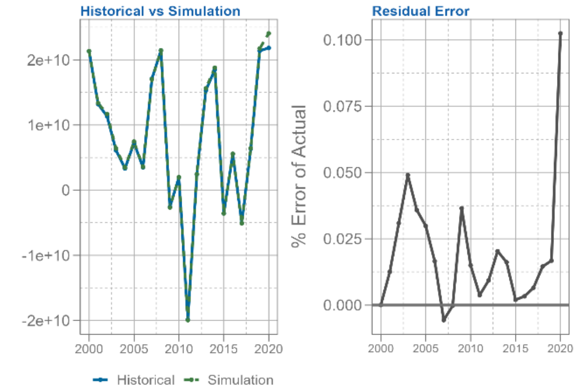
Fer Unmet Need For Family Planning



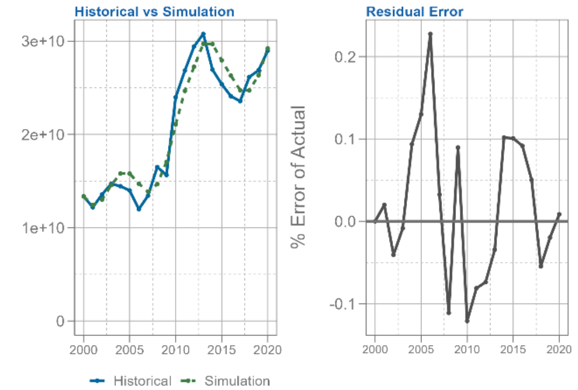
Fin Domestic Financing



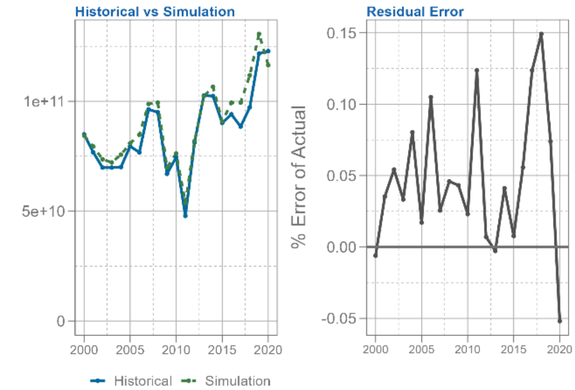
Fin Foreign Financing



Fin Gross International Reserves



Fin Private Domestic Investment



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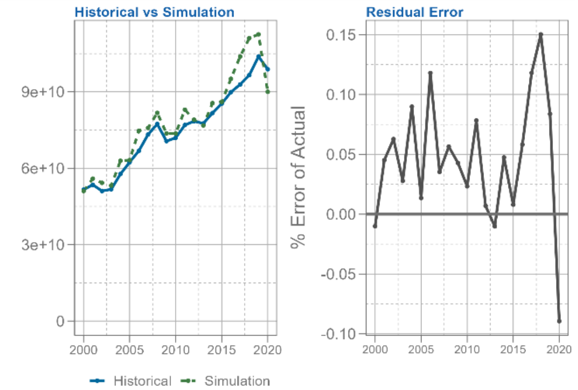
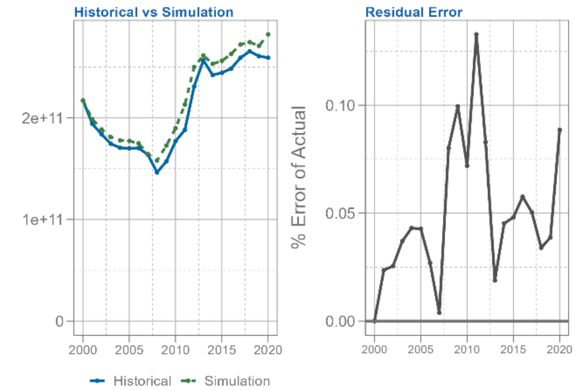


Fin Public Domestic Debt



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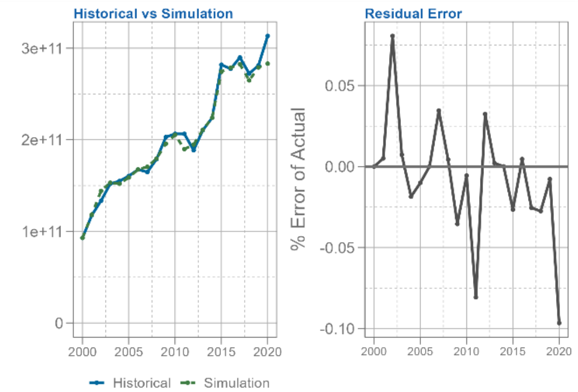
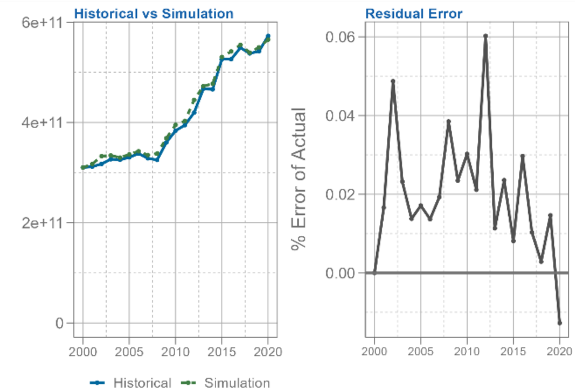
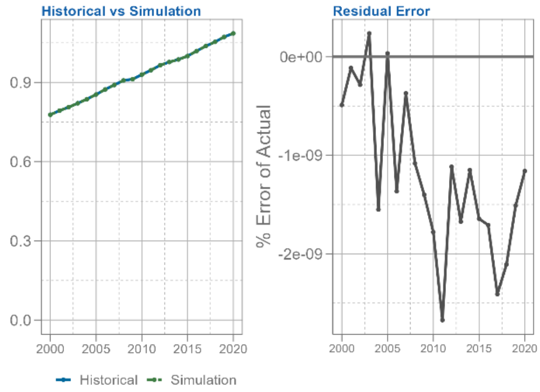


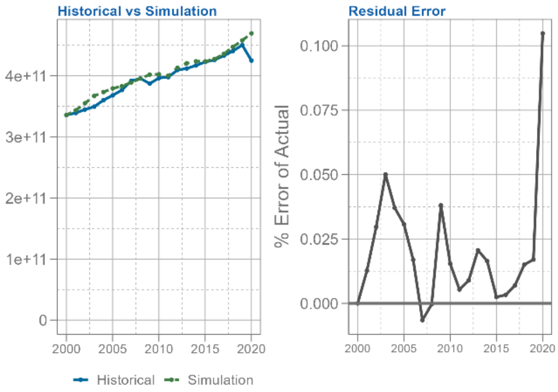
Fin Total Public Debt



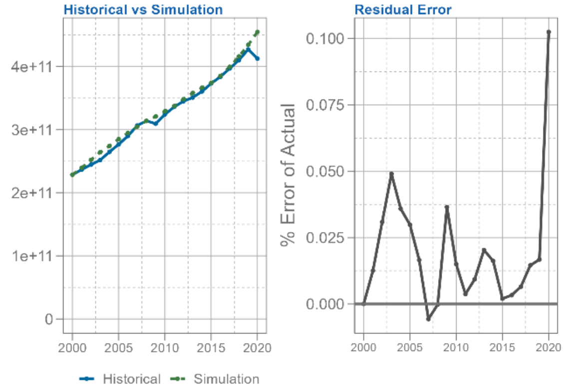
Gdp Gdp Mp Deflator



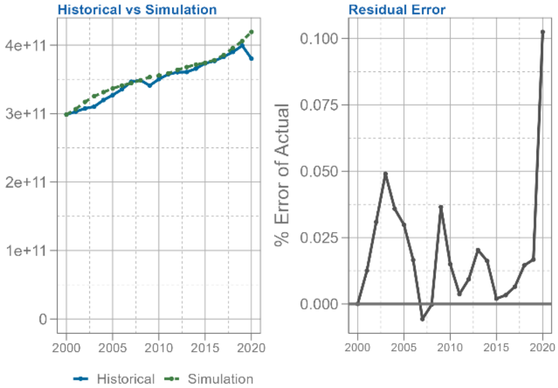
Gdp Gross National Income



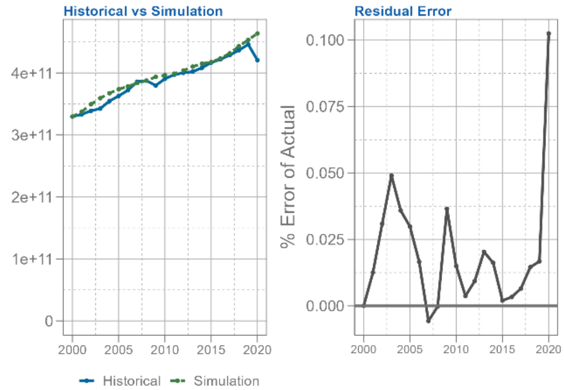
Gdp Nominal Gdp Fc



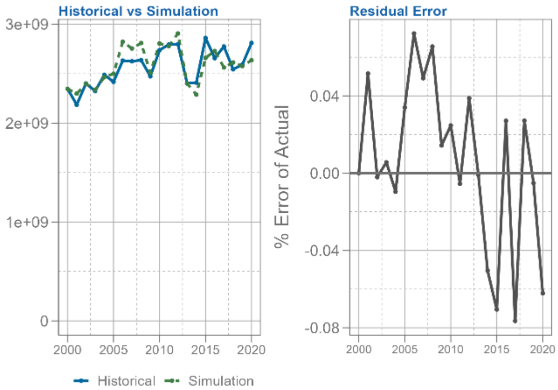
Gdp Real Gdp Fc



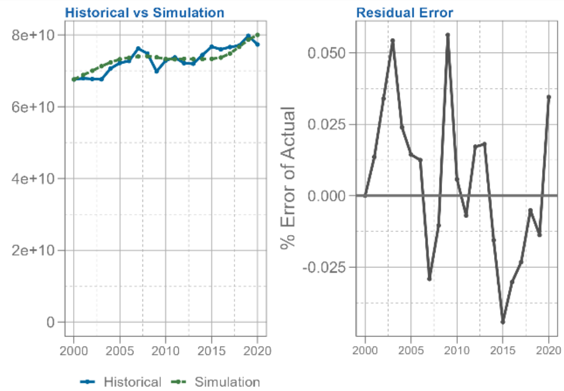
Gdp Real Gdp Mp



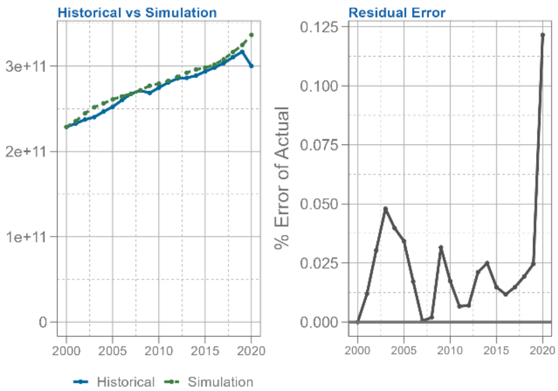
Gdp Total Agriculture Production



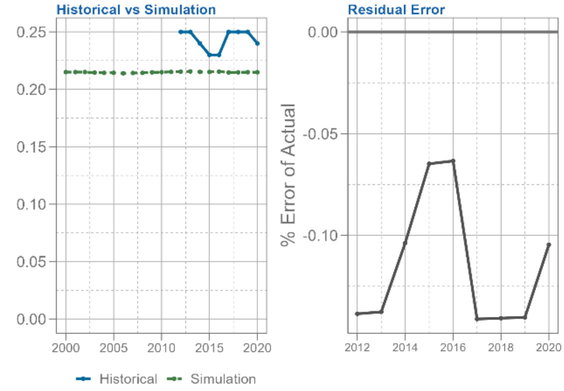
Gdp Total Industry Production



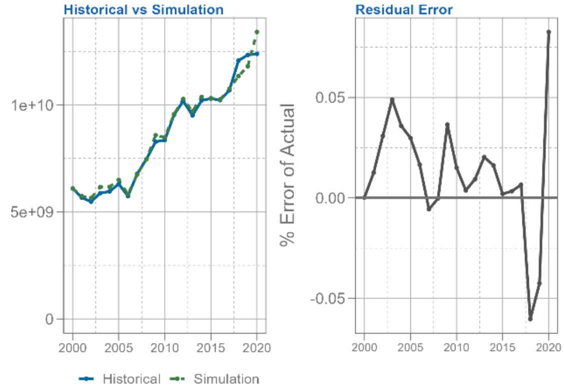
Gdp Total Services Production



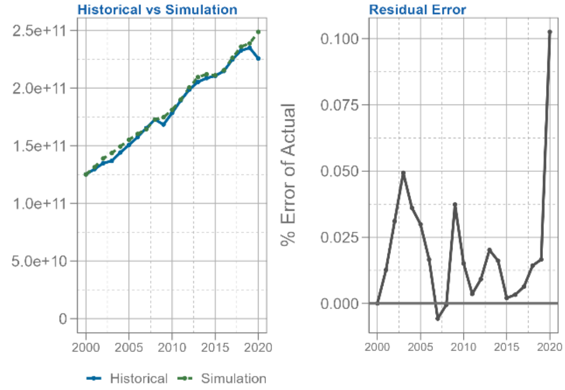
Gnc Bribery Incidence



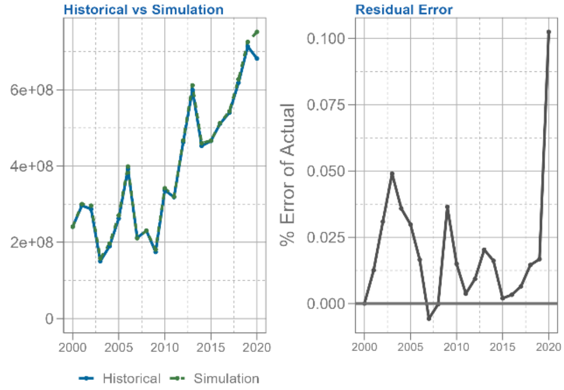
Gov Government Investment



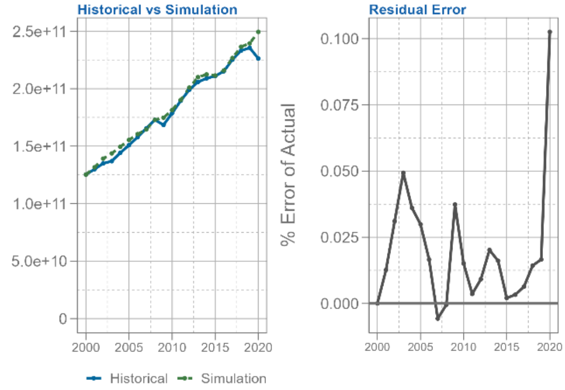
Gov Government Revenue



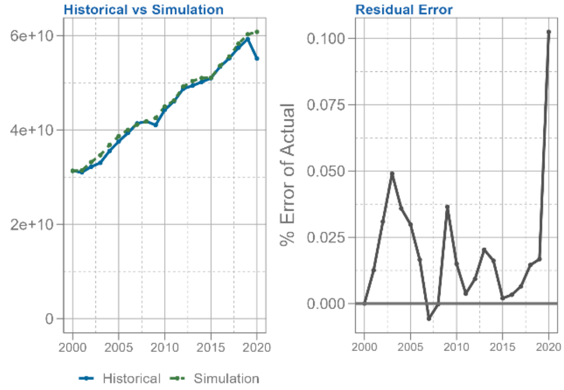
Gov Grants



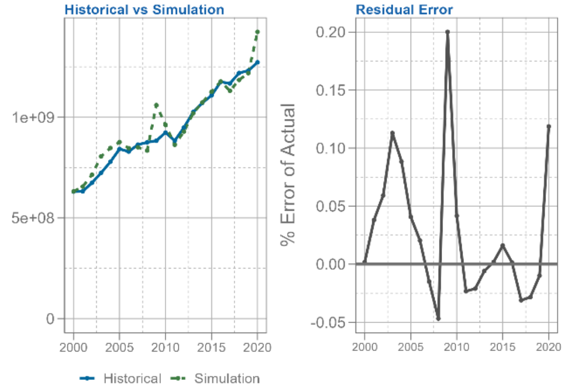
Gov Revenue And Grants



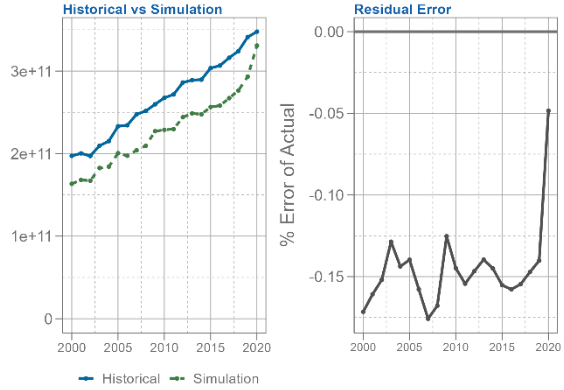
Gov Taxes On Goods And Services



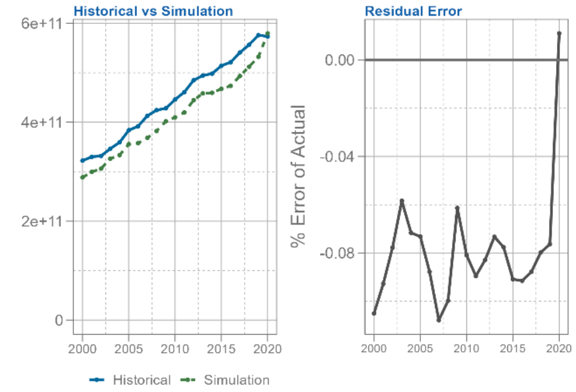
Gov Taxes On International Trade



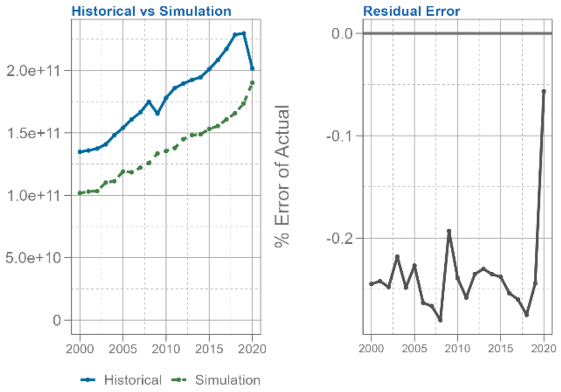
Hhs Disposable Income



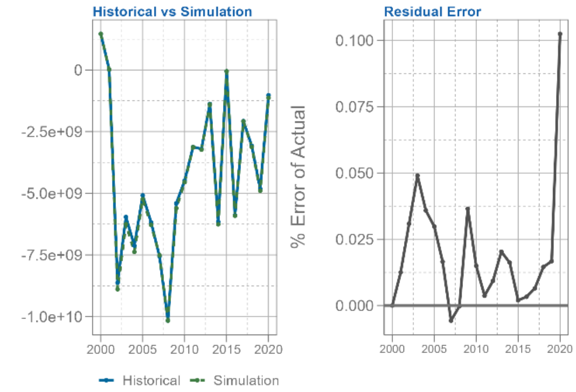
Hhs Households Revenue



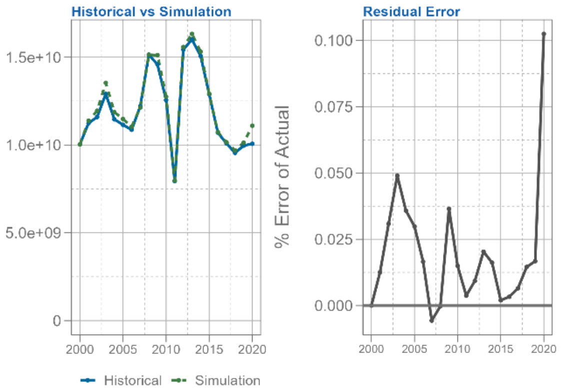
Hhs Private Consumption



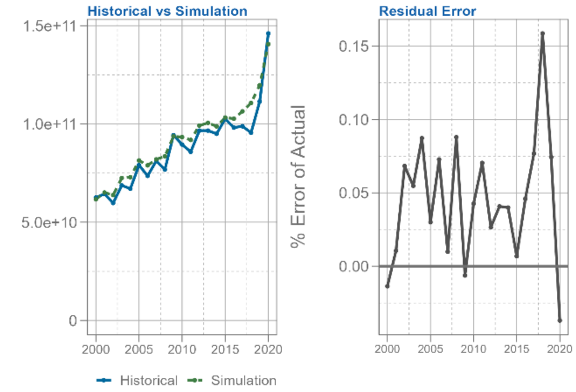
Hhs Private Current Transfers



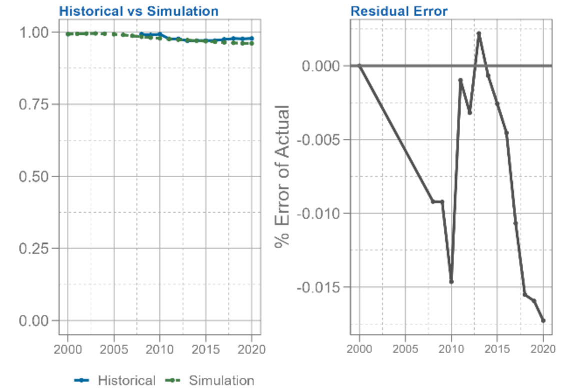
Hhs Private Factor Income



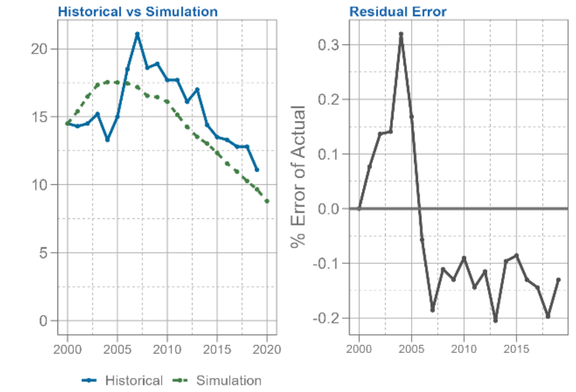
Hhs Private Saving



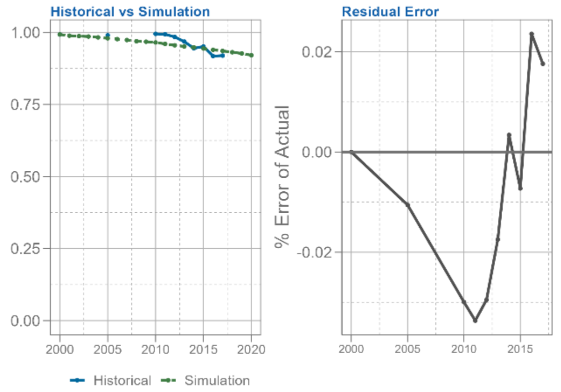
Hlt Average Access To Basic Health Care



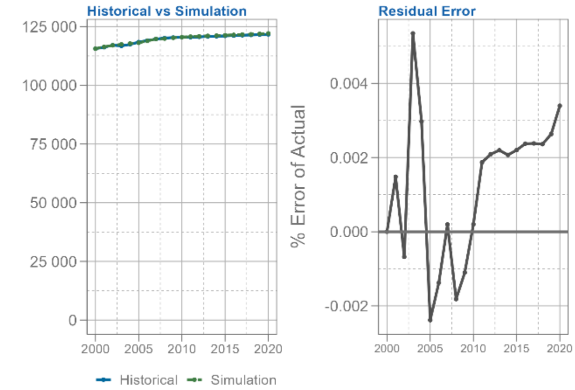
Hlt Pm 25 Mean Annual Exposure



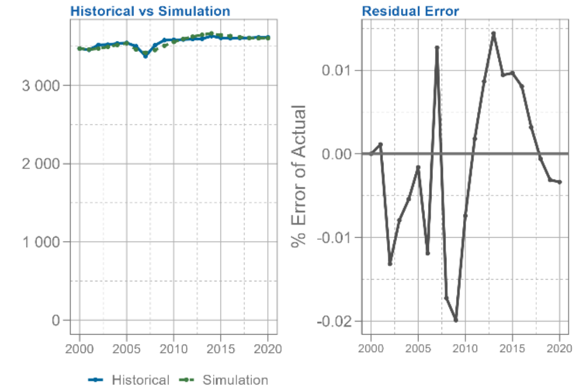
Hlt Proportion Of Population Exposed To Pm 25 Levels Exceeding \



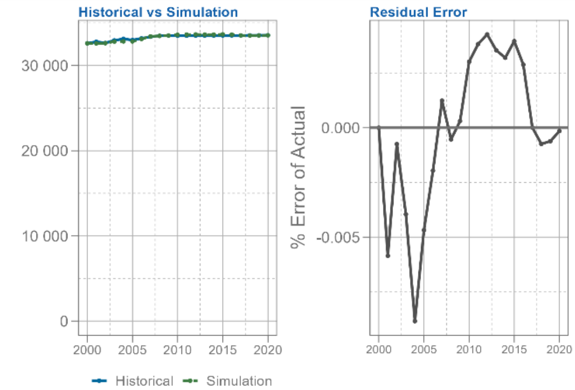
Ifr Infrastructure[Paved]



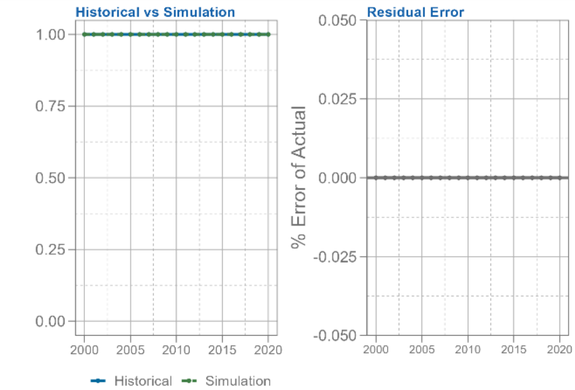
Ifr Infrastructure[Rail]



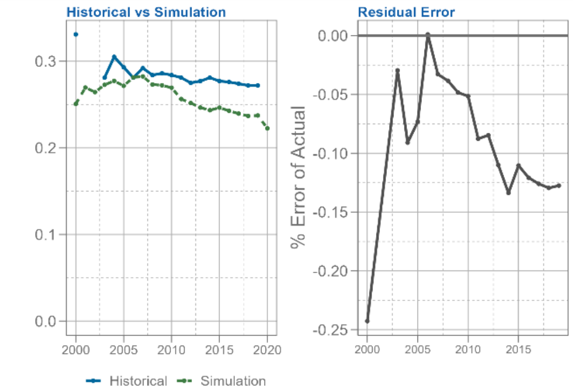
Ifr Infrastructure[Unpaved]



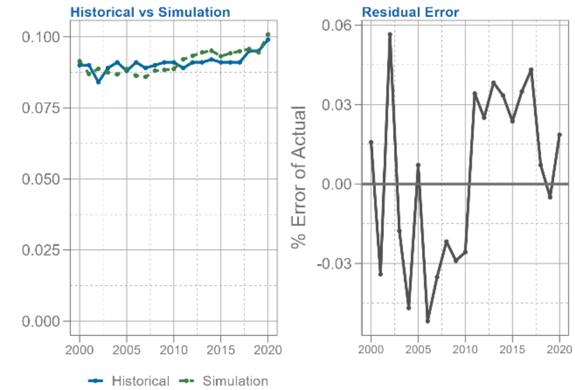
Ifr Rural Access Index



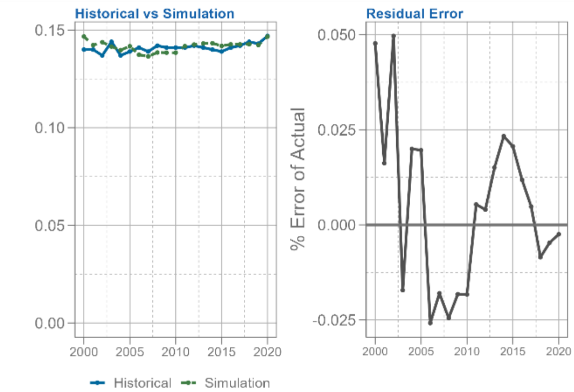
Inc Gini Coefficient



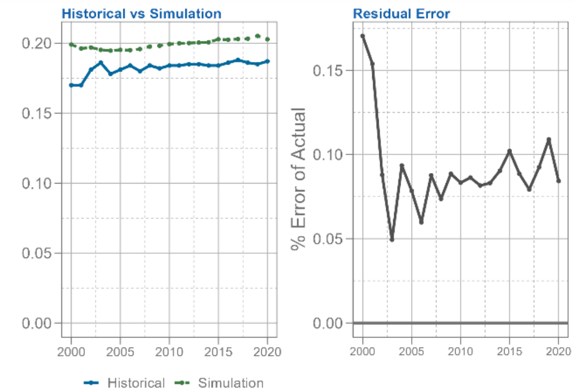
Inc Income Share By Quintile[Q1]



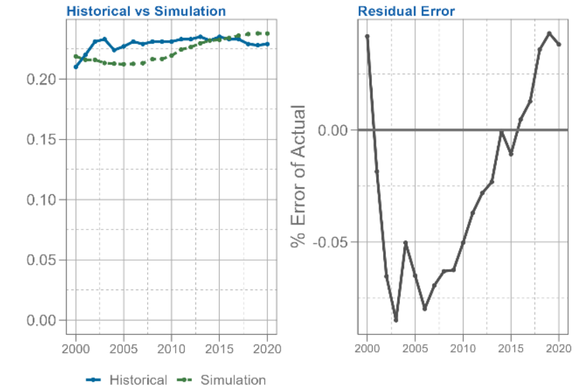
Inc Income Share By Quintile[Q2]



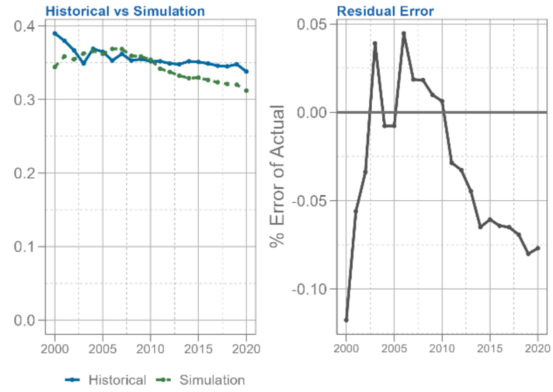
Inc Income Share By Quintile[Q3]



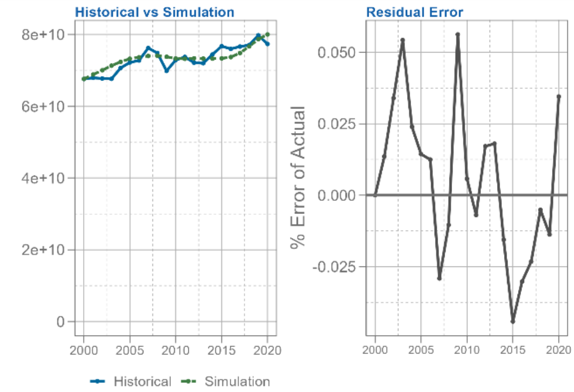
Inc Income Share By Quintile[Q4]



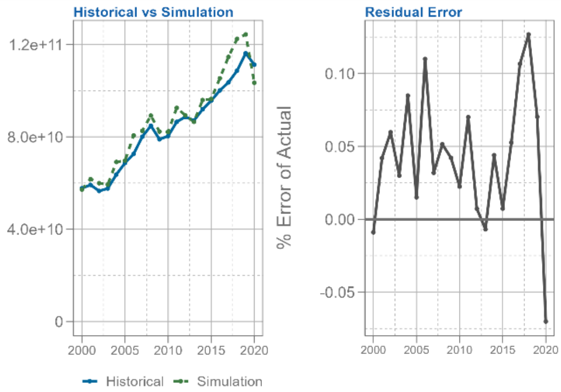
Inc Income Share By Quintile[Q5]



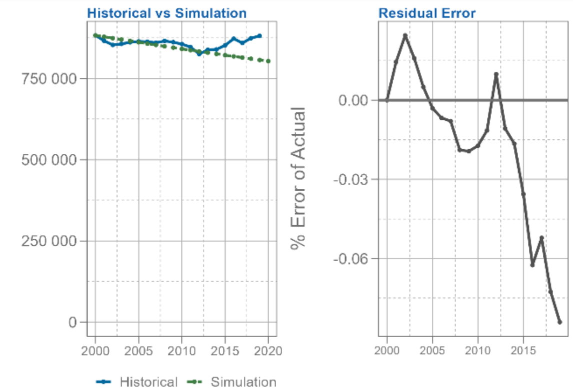
Ind Industry Production[Ind 1]



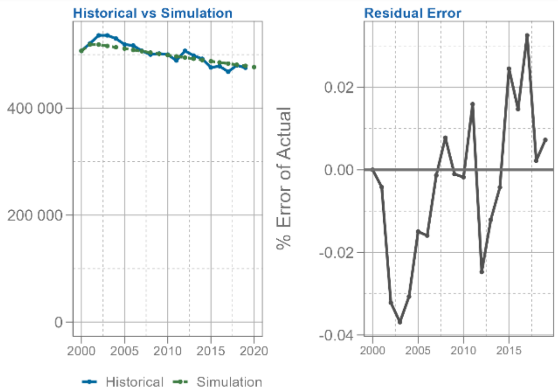
Inv Investment



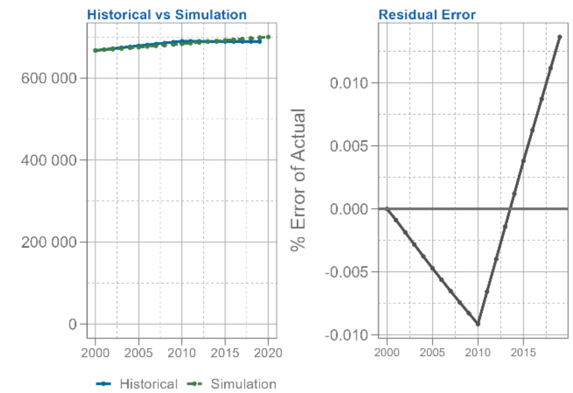
Lnd Agriculture Land[Agr 1]



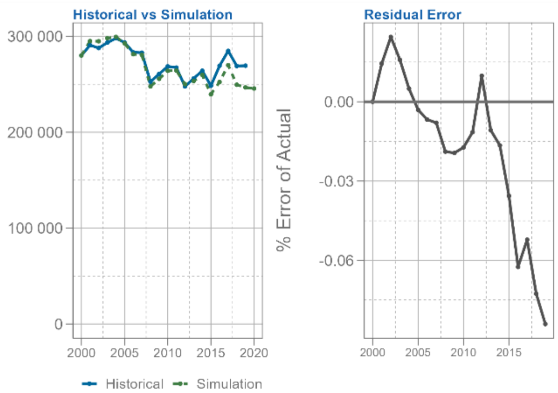
Lnd Agriculture Land[Agr 2]



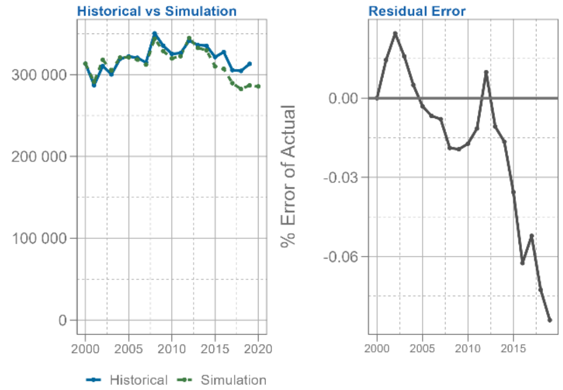
Lnd Forest Land



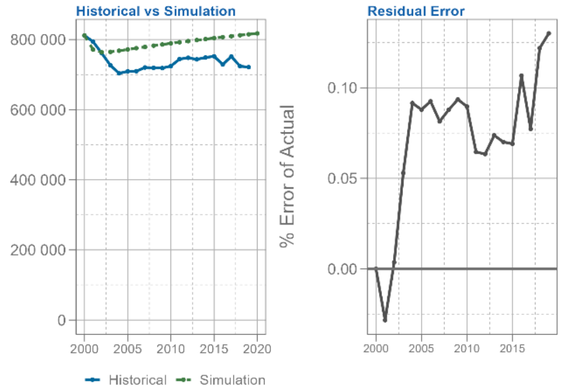
Lnd Harvested Area[Crop 1]



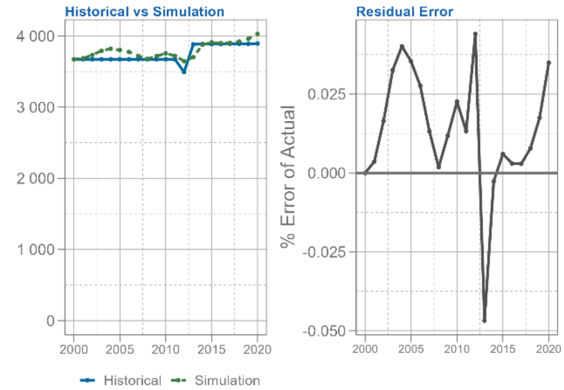
Lnd Harvested Area[Crop 2]



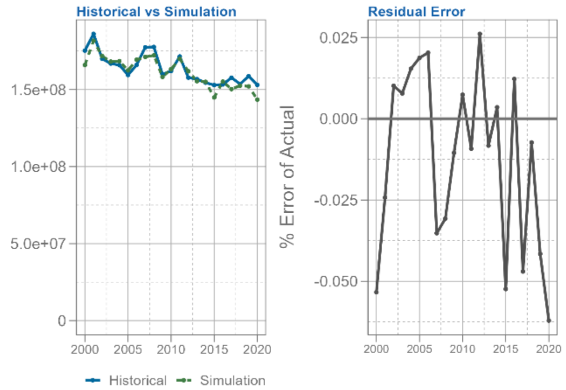
Lnd Other Land



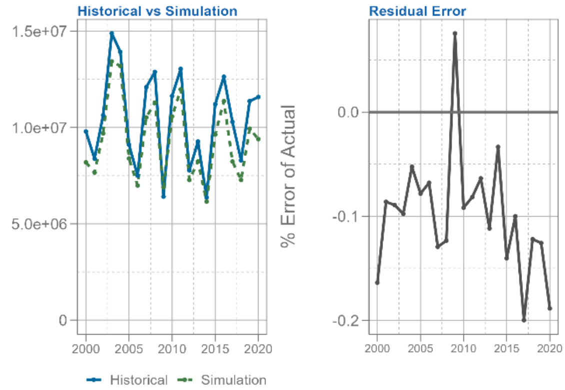
Lnd Terrestrial Areas Formally Protected



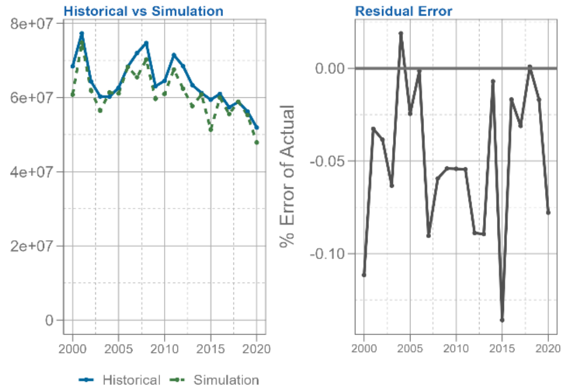
Mat Domestic Material Consumption



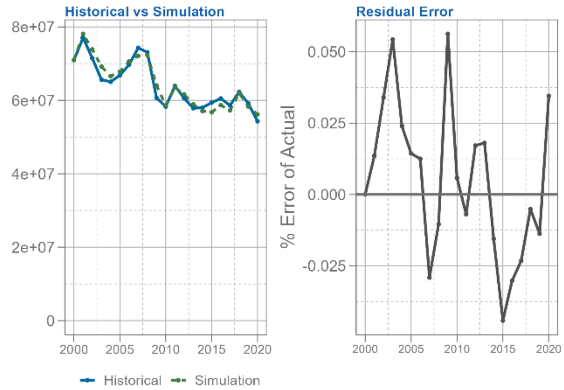
Mat Minerals And Metals Consumption[Metal Ores]



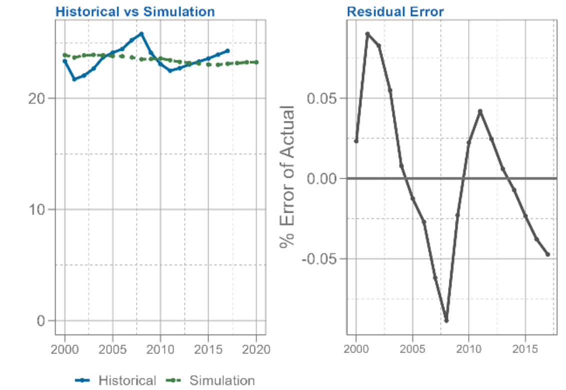
Mat Minerals And Metals Consumption[Non Metallic Minerals]



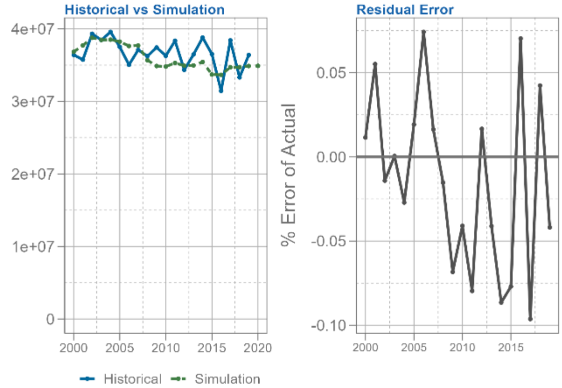
Mat Minerals And Metals Extraction[Non Metallic Minerals]



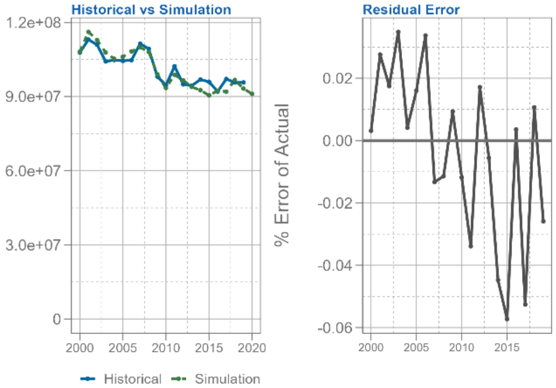
Mat Pc Material Footprint



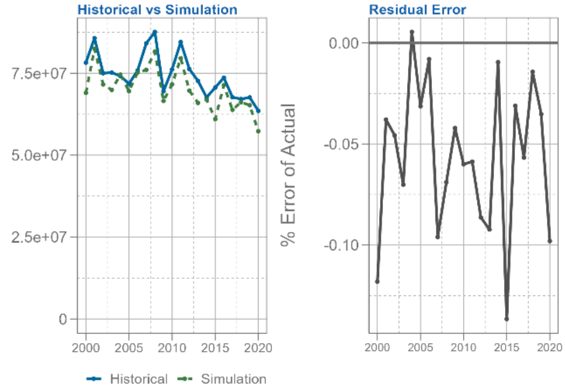
Mat Total Biomass Extraction



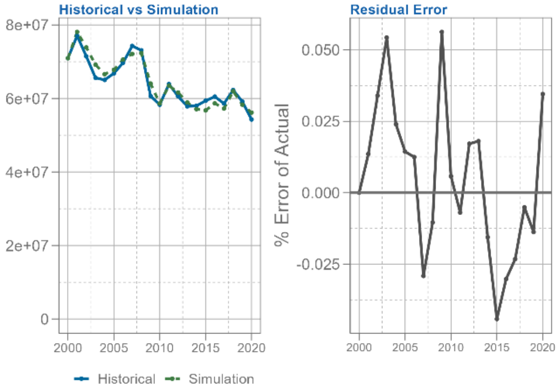
Mat Total Material Extraction



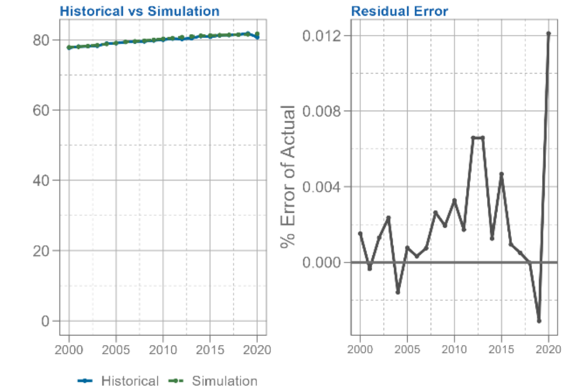
Mat Total Minerals And Metal Ores Consumption



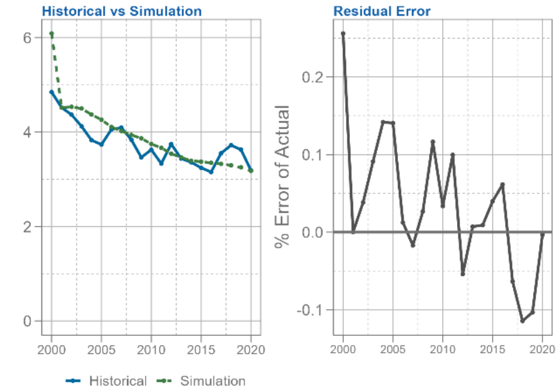
Mat Total Minerals And Metal Ores Extraction



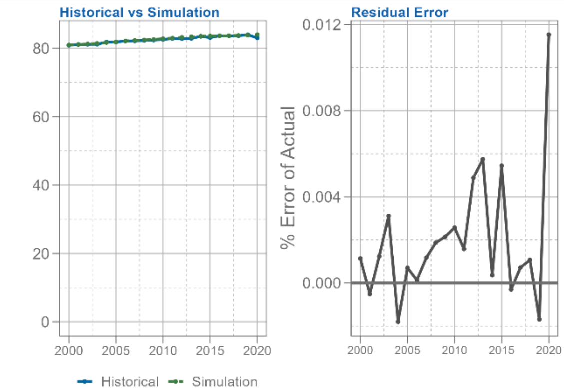
Mor Average Life Expectancy



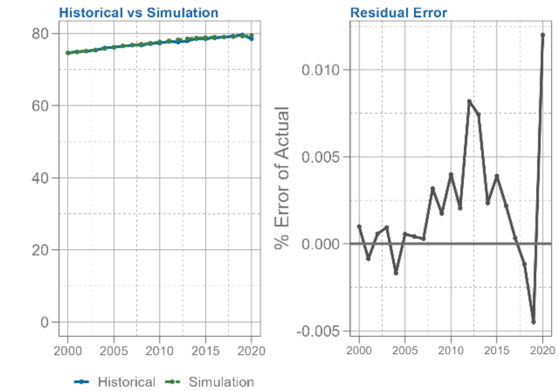
Mor Infant Mortality Rate



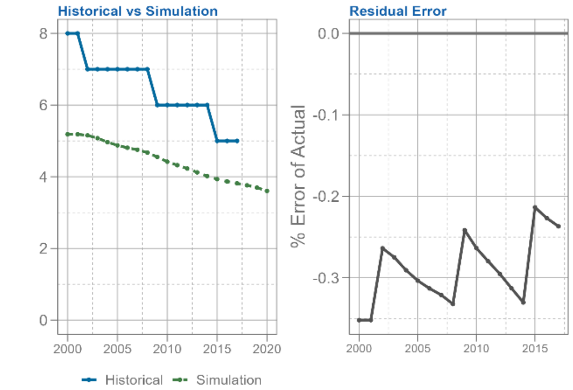
Mor Life Expectancy[Female]



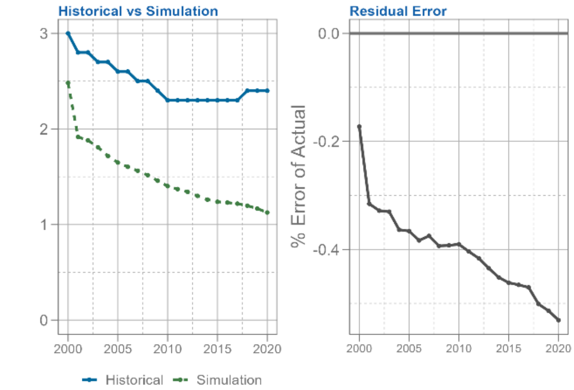
Mor Life Expectancy[Male]



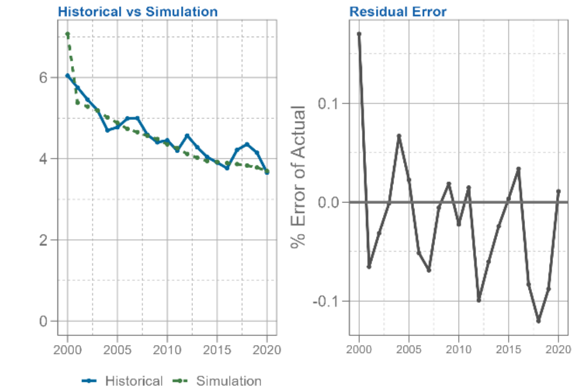
Mor Maternal Mortality Ratio



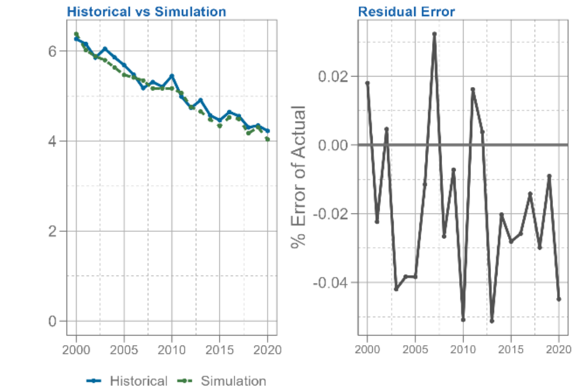
Mor Neonatal Mortality Rate



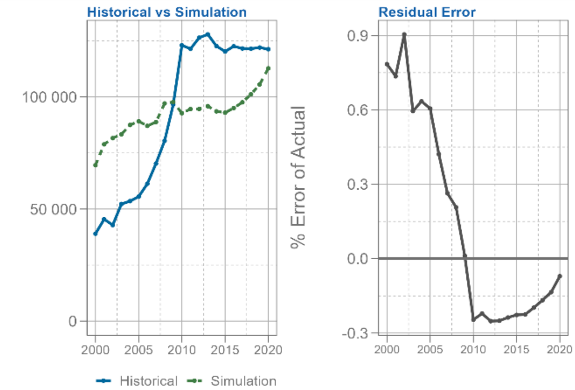
Mor Under Five Mortality Rate



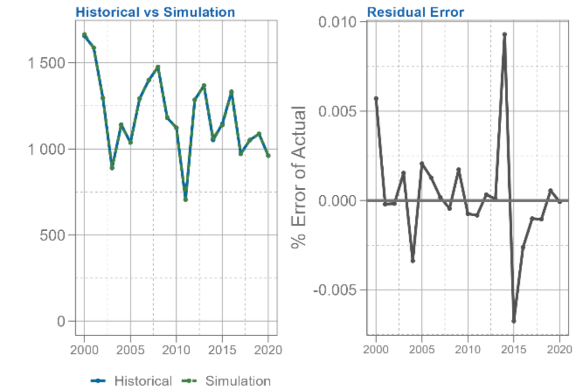
Pes Energy Intensity Level Of Primary Energy



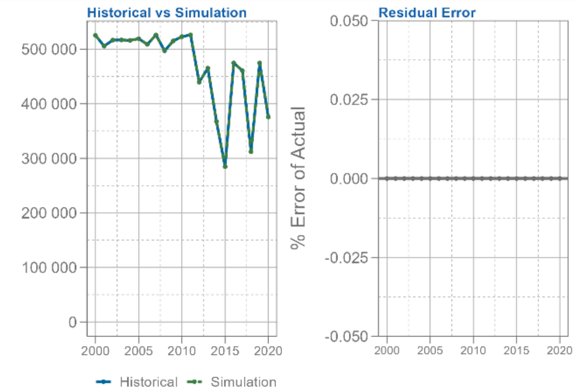
Pes Primary Energy Production[Bio]



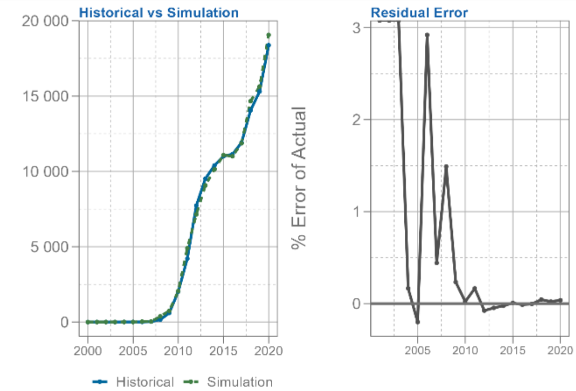
Pes Primary Energy Production[Hydro]



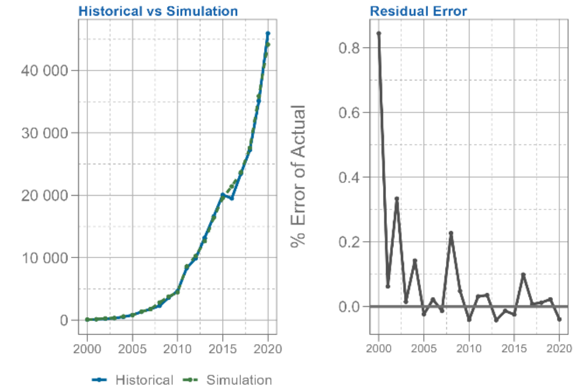
Pes Primary Energy Production[Nuclear]



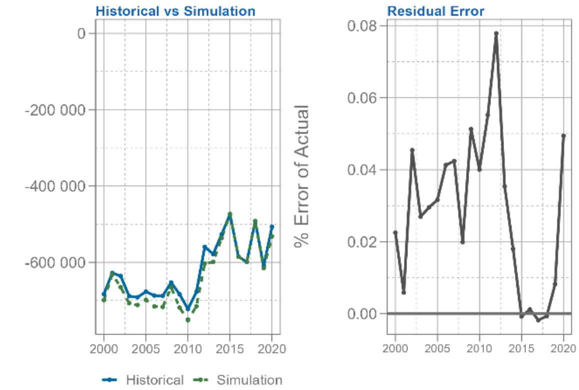
Pes Primary Energy Production[Solar]



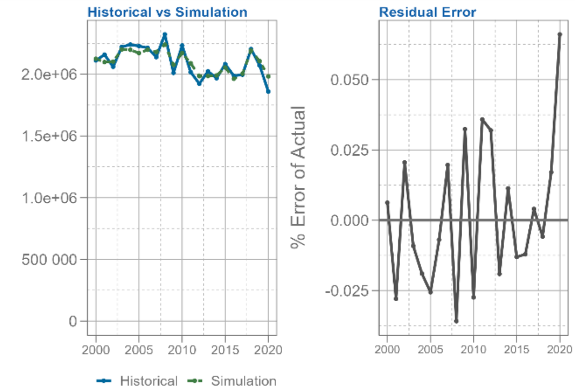
Pes Primary Energy Production[Wind]



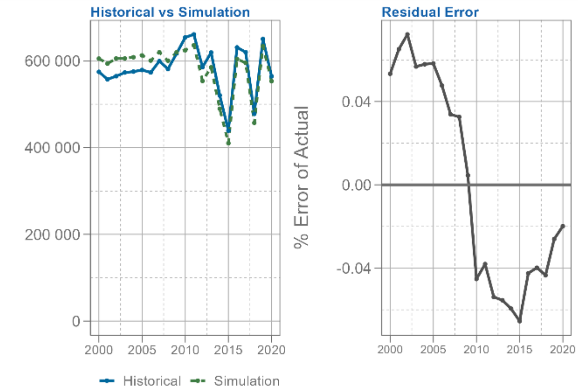
Pes Total Energy Transformation And Losses



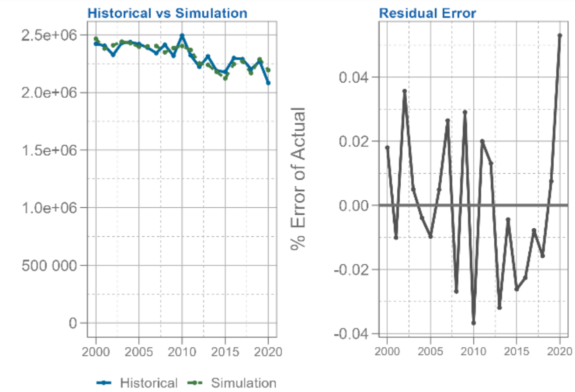
Pes Total Primary Energy Net Import



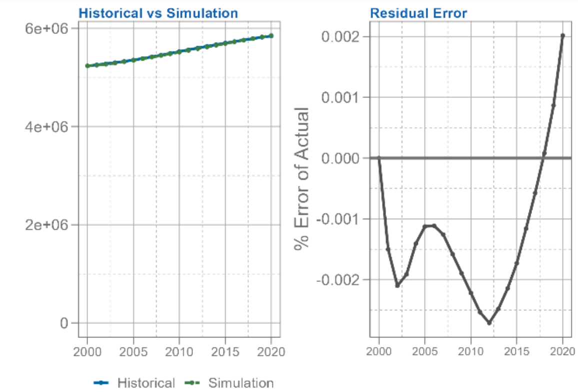
Pes Total Primary Energy Production



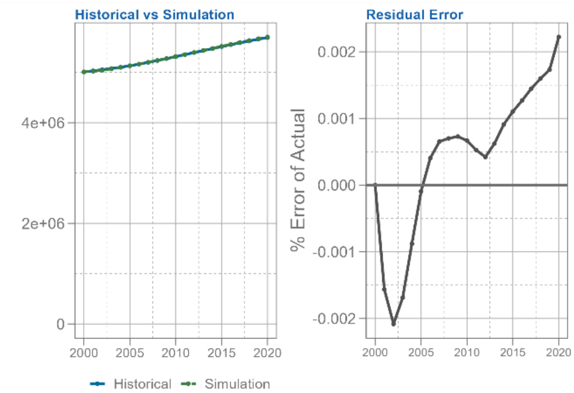
Pes Total Primary Energy Supply



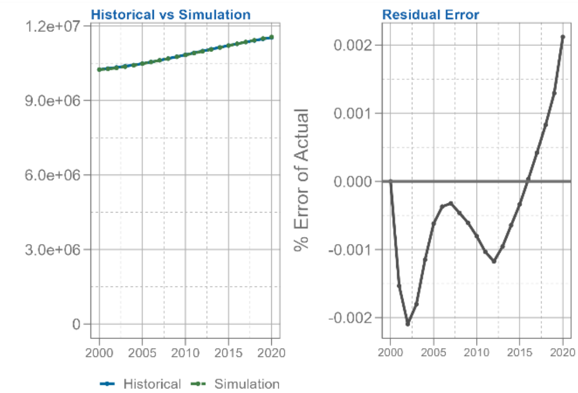
Pop Population By Gender[Female]



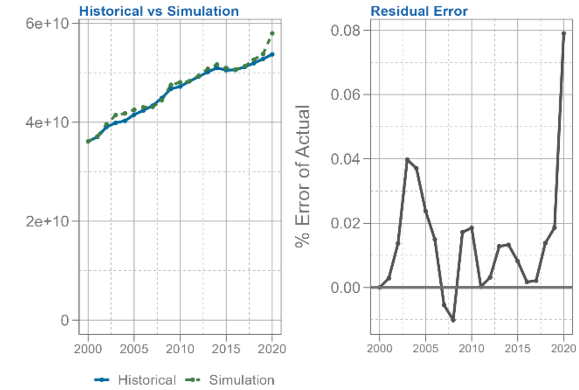
Pop Population By Gender[Male]



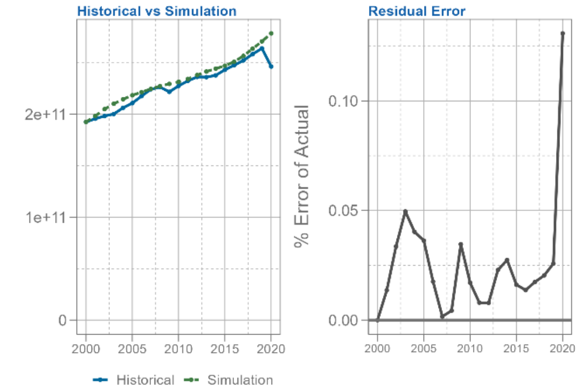
Pop Total Population



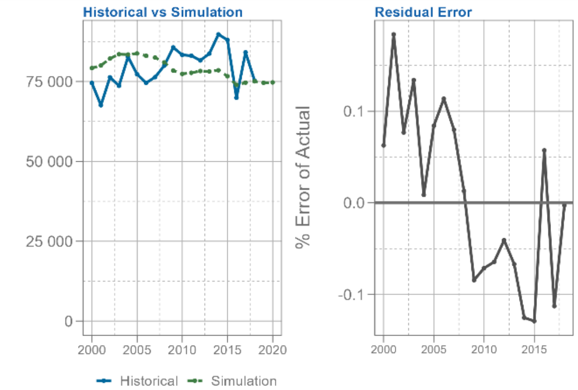
Ser Public Services Production



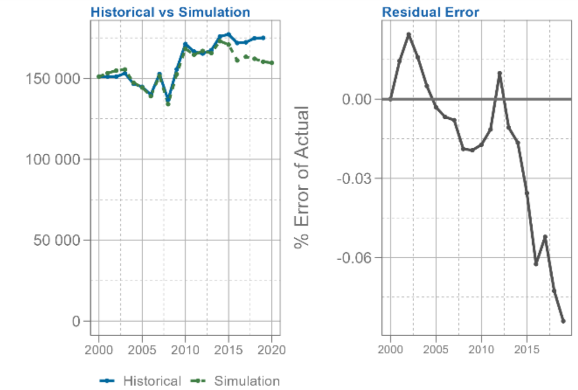
Ser Services Production[Ser 1]



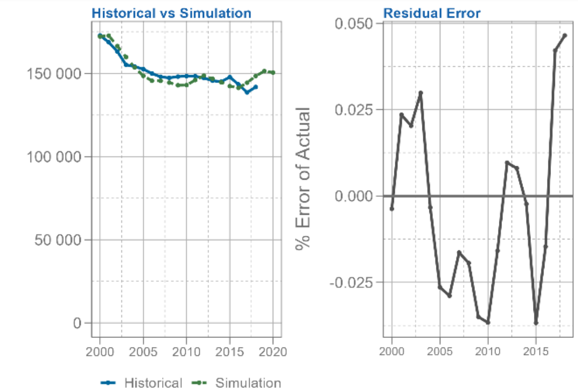
Sln Crop Nutrient Uptake[N]



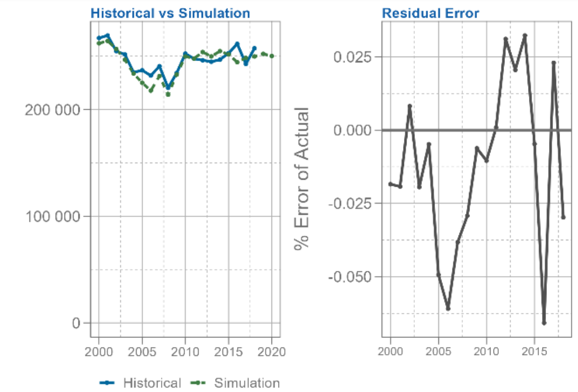
Sln Fertilizer Consumption[N]



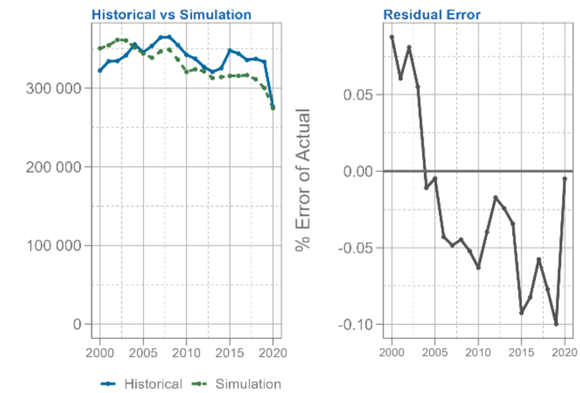
Sln Nutrient From Manure Application[N]



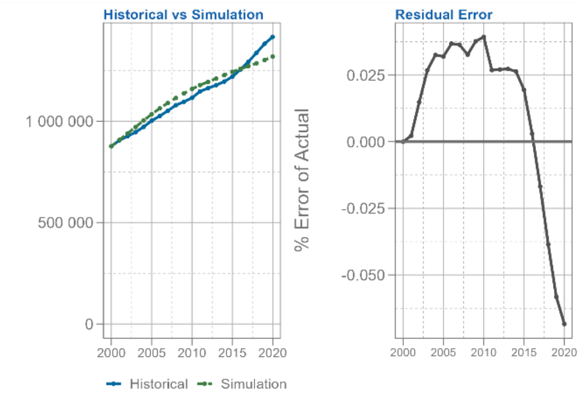
Sln Soil Primary Nitrogen Balance



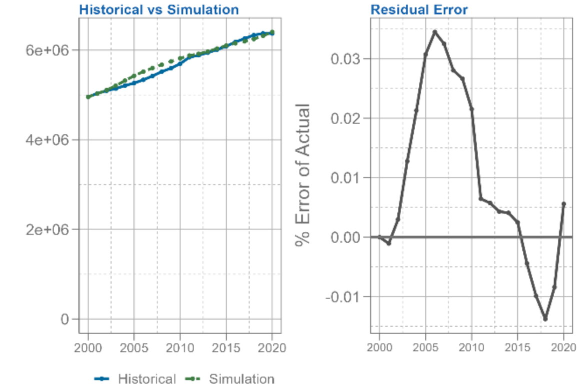
Veh Total Motor Fuel Consumption



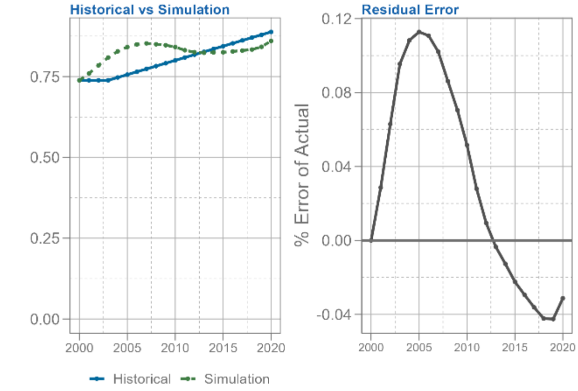
Veh Total Vehicles By Type[Commercial, Ic]



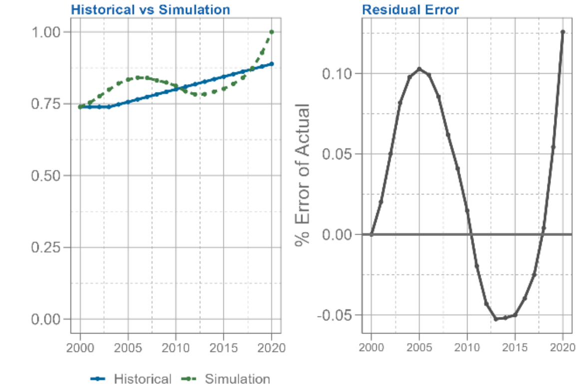
Veh Total Vehicles By Type[Passenger, lc]



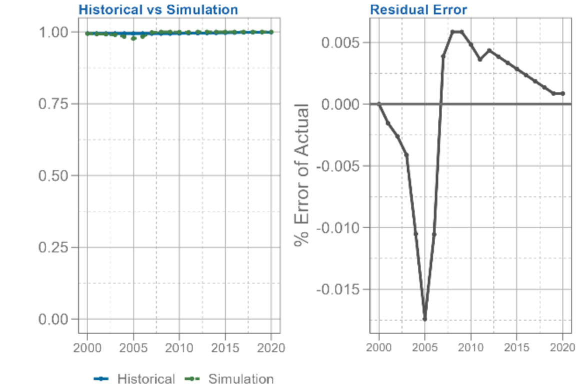
Was Access To Safely Managed Sanitation Facility[Rural]



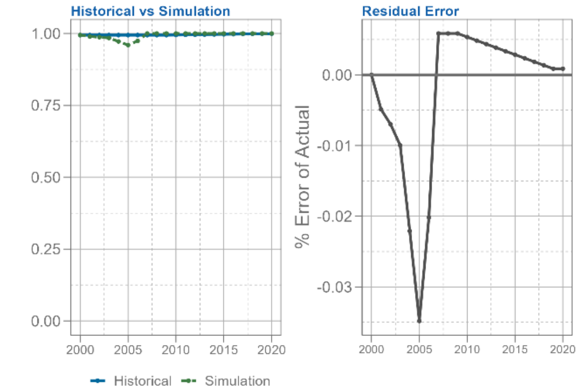
Was Access To Safely Managed Sanitation Facility[Urban]



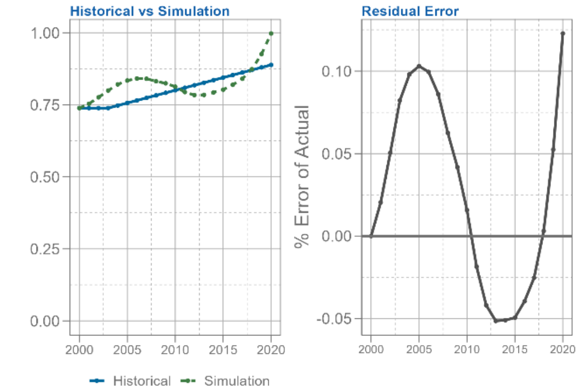
Was Access To Safely Managed Water Source[Rural]



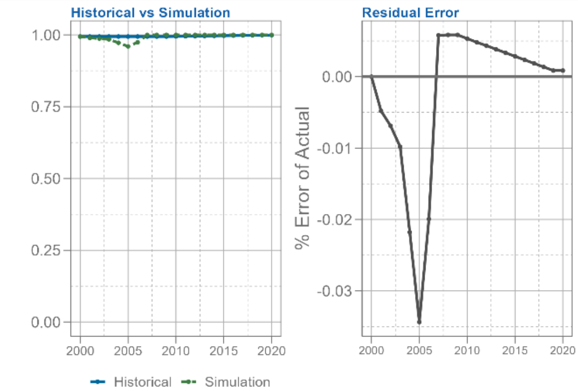
Was Access To Safely Managed Water Source[Urban]



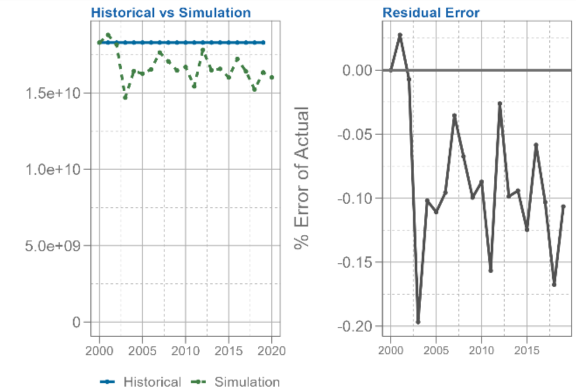
Was Average Access To Safely Managed Sanitation Facility



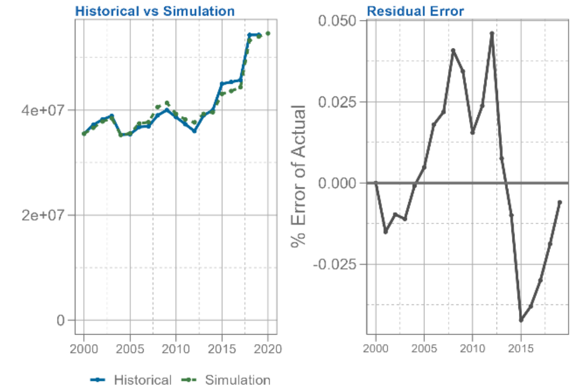
Was Average Access To Safely Managed Water Source



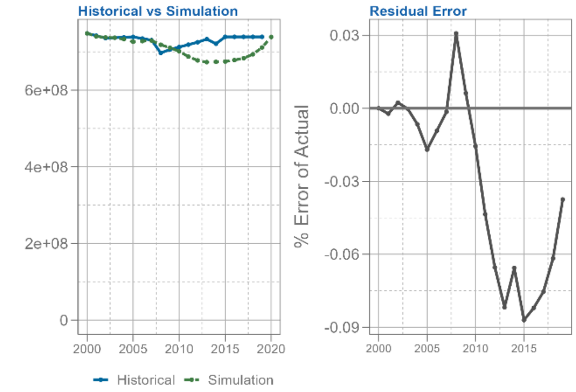
Was Total Renewable Water Resources



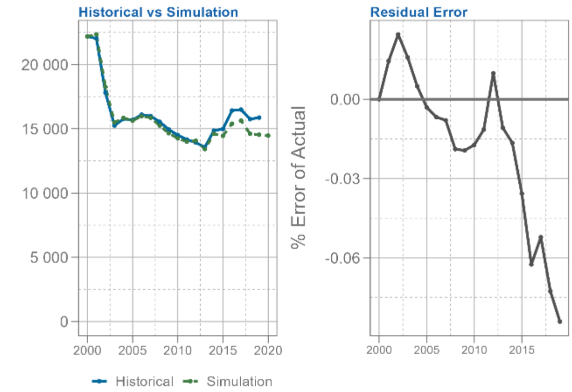
Waw Agriculture Water Withdrawal



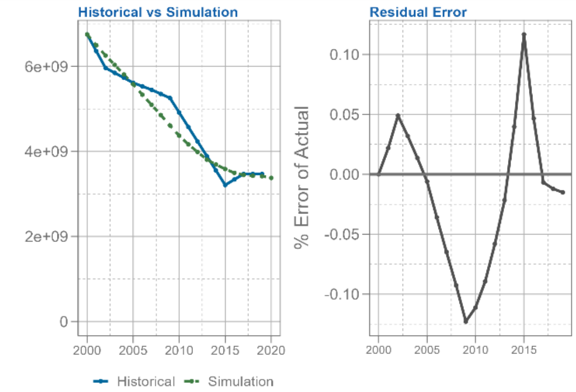
Waw Domestic And Municipal Water Withdrawal



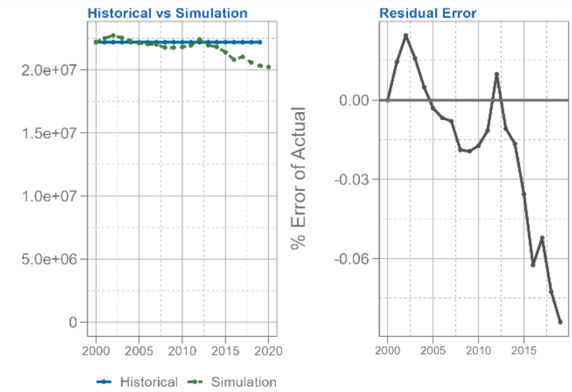
Waw Harvested Area Irrigated



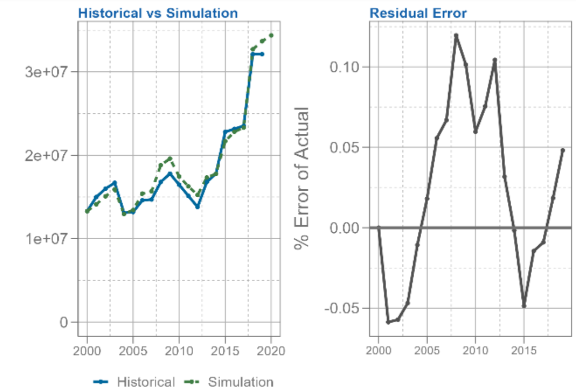
Waw Industry Water Withdrawal



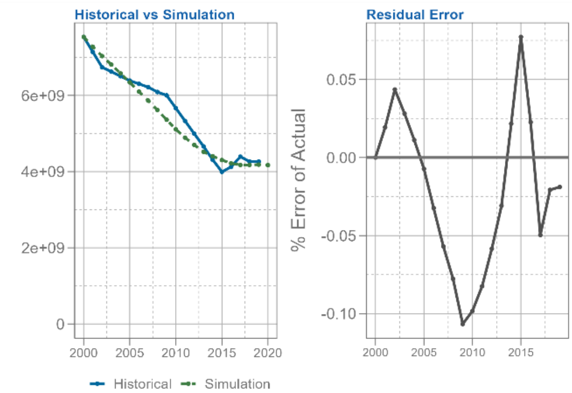
Waw Irrigation Water Withdrawal



Waw Livestock Water Withdrawal



Waw Total Water Withdrawal



Annexe 3 - Parameter Values

Table 7 – Parameter values and ranges

Parameter	Value	Minimum	Maximum
Agr.agriculture capital elasticity[agr 1]	0.37	0.2	0.4
Agr.agriculture capital elasticity[agr 2]	0.78	0.2	0.8
Agr.agriculture capital elasticity[agr 3]	0.70	0.2	0.7
Agr.agriculture capital elasticity[agr 4]	0.41	0.05	0.5
Agr.agriculture capital elasticity[agr 5]	0.50	0.2	0.5
Agr.agriculture labor elasticity[agr 1]	0.23	0.2	0.4
Agr.agriculture productivity adjustment time[agr 1]	3.00	1	3
Agr.agriculture productivity adjustment time[agr 2]	2.90	1	3
Agr.agriculture productivity adjustment time[agr 3]	1.60	1	3
Agr.agriculture productivity adjustment time[agr 4]	10.00	1	10
Agr.agriculture productivity adjustment time[agr 5]	1.57	1	3
Agr.elasticity of capture to fish resources availability	1.12	0.25	2
Agr.elasticity of forestry productivity to available forest	0.60	0.1	0.6
Agr.elasticity of productivity to education agriculture[agr 1]	0.40	0.2	0.4
Agr.elasticity of productivity to education agriculture[agr 2]	0.60	0.01	0.6
Agr.elasticity of productivity to education agriculture[agr 3]	0.59	0.2	0.7
Agr.elasticity of productivity to education agriculture[agr 4]	0.00	0	0.6
Agr.elasticity of productivity to education agriculture[agr 5]	0.70	0.2	0.7
Agr.elasticity of productivity to electrification agriculture[agr 1]	0.04	0.025	0.1
Agr.elasticity of productivity to electrification agriculture[agr 2]	0.03	0.025	0.15
Agr.elasticity of productivity to electrification agriculture[agr 3]	0.07	0.02	0.1
Agr.elasticity of productivity to electrification agriculture[agr 4]	0.20	0.025	0.2
Agr.elasticity of productivity to electrification agriculture[agr 5]	0.04	0.025	0.2
Agr.elasticity of productivity to female participation agriculture[agr 1]	0.30	0.05	0.3
Agr.elasticity of productivity to female participation agriculture[agr 2]	0.25	0.05	0.4
Agr.elasticity of productivity to female participation agriculture[agr 3]	0.40	0.05	0.4
Agr.elasticity of productivity to female participation agriculture[agr 4]	0.00	0	0.3
Agr.elasticity of productivity to female participation agriculture[agr 5]	0.30	0.05	0.3
Agr.elasticity of productivity to governance agriculture[agr 1]	0.05	0.05	0.4
Agr.elasticity of productivity to governance agriculture[agr 2]	0.59	0.05	0.6
Agr.elasticity of productivity to governance agriculture[agr 3]	0.60	0.05	0.6
Agr.elasticity of productivity to governance agriculture[agr 4]	1.50	0.05	1.5
Agr.elasticity of productivity to governance agriculture[agr 5]	0.42	0.05	0.5
Agr.elasticity of productivity to inflation agriculture[agr 1]	-0.03	-0.1	-0.025
Agr.elasticity of productivity to inflation agriculture[agr 2]	-0.03	-0.12	-0.025
Agr.elasticity of productivity to inflation agriculture[agr 3]	-0.02	-0.1	-0.02
Agr.elasticity of productivity to inflation agriculture[agr 4]	-1.50	-1.5	-0.025
Agr.elasticity of productivity to inflation agriculture[agr 5]	-0.01	-0.1	-0.01
Agr.elasticity of productivity to infrastructure density agriculture[agr 1]	0.10	0.025	0.1
Agr.elasticity of productivity to infrastructure density agriculture[agr 2]	0.02	0.01	0.3
Agr.elasticity of productivity to infrastructure density agriculture[agr 3]	0.20	0.025	0.2
Agr.elasticity of productivity to infrastructure density agriculture[agr 4]	0.00	0	0.1
Agr.elasticity of productivity to infrastructure density agriculture[agr 5]	0.10	0.025	0.1
Agr.elasticity of productivity to life expectancy agriculture[agr 1]	0.40	0.1	0.4

Parameter	Value	Minimum	Maximum
Agr.elasticity of productivity to life expectancy agriculture[agr 2]	0.33	0.1	0.4
Agr.elasticity of productivity to life expectancy agriculture[agr 3]	0.50	0.1	0.5
Agr.elasticity of productivity to life expectancy agriculture[agr 4]	0.00	0	0.4
Agr.elasticity of productivity to life expectancy agriculture[agr 5]	0.40	0.1	0.4
Agr.elasticity of productivity to public agriculture expenditure[agr 1]	0.05	0.05	0.1
Agr.elasticity of productivity to public agriculture expenditure[agr 2]	0.05	0.05	0.2
Agr.elasticity of productivity to public agriculture expenditure[agr 3]	0.01	0.01	0.1
Agr.elasticity of productivity to public agriculture expenditure[agr 4]	1.50	0.05	1.5
Agr.elasticity of productivity to public agriculture expenditure[agr 5]	0.01	0.01	0.1
Agr.elasticity of productivity to trade agriculture[agr 1]	0.20	0.025	0.2
Agr.elasticity of productivity to trade agriculture[agr 2]	0.60	0.025	0.6
Agr.elasticity of productivity to trade agriculture[agr 3]	0.40	0.025	0.4
Agr.elasticity of productivity to trade agriculture[agr 4]	0.00	0	0.2
Agr.elasticity of productivity to trade agriculture[agr 5]	0.20	0.01	0.2
Agr.elasticity of productivity to water availability livestock	0.00	0.001	0.4
Agr.elasticity of yield to productivity by crop[crop 1]	2.00	0.5	2
Agr.elasticity of yield to productivity by crop[crop 2]	0.50	0.5	2
Agr.indicated to actual initial agriculture productivity ratio[agr 1]	1.05	0.95	1.05
Agr.indicated to actual initial agriculture productivity ratio[agr 2]	0.90	0.8	1.05
Agr.indicated to actual initial agriculture productivity ratio[agr 3]	1.10	0.95	1.1
Agr.indicated to actual initial agriculture productivity ratio[agr 4]	0.30	0.3	1.05
Agr.indicated to actual initial agriculture productivity ratio[agr 5]	1.10	0.95	1.1
Agr.macro substitution factor[crop 1]	0.39	0.2	2
Agr.macro substitution factor[crop 2]	0.59	0.2	2
Agr.nutrient geographical variability compounded aquisition factor[crop 1]	0.76	0.2	2
Agr.nutrient geographical variability compounded aquisition factor[crop 2]	0.20	0.2	2
Agr.potential to initial yield ratio[crop 1]	4.34	1	5
Agr.potential to initial yield ratio[crop 2]	2.24	1	5
Agr.water distribution factor[crop 1]	0.05	0.05	2
Agr.water distribution factor[crop 2]	0.05	0.05	2
BDv.biodiversity loss risk adjustment	0.10	0.1	1.1
BDv.effect of n emissions on biodiversity multiplier	0.00	0.0001	0.001
BDv.elasticity of biodiversity to average temperature	0.05	0.05	0.15
BDv.elasticity of biodiversity to forest land	0.56	0.1	0.75
BDv.elasticity of biodiversity to precipitation	0.05	0.05	0.15
BDv.elasticity of fish stock sustainably exploited to fish resources availability	1.01	0.1	2
BDv.initial estimated capture to full stock ratio[fish 1]	0.48	0	1
BDv.natural fish stock regrowth time[fish 1]	121.22	5	1000
BoP.elasticity of export share to productivity	1.74	0.1	2.5
BoP.indicated to actual initial export ratio	1.00	0.75	1.25
BoP.multiplier of export share to taxes on international trade	-4.35	-10	-0.05
BoP.time to perceive changes in productivity	1.00	1	4
BoP.time to perceive changes in taxes on international trade	4.00	0.5	4
Con.biomass pm 25 emission per mj	0.08	0.06	0.1
Con.pm25 emissions per petajoule	0.02	0.019	0.035

Parameter	Value	Minimum	Maximum
Edu.education expenditure past growth rate[E1]	-0.15	-0.15	0.1
Edu.education expenditure past growth rate[E3]	0.03	-0.1	0.3
Edu.education expenditure past growth rate[E5]	0.07	-0.1	0.1
Edu.elasticity of dropout to crowding	0.05	0.05	0.25
Edu.elasticity of dropout to pre primary education	-0.01	-0.1	-0.01
Edu.elasticity of enrollment to infrastructure density[E1]	0.06	0.05	0.25
Edu.elasticity of enrollment to infrastructure density[E3]	0.23	0.05	0.25
Edu.elasticity of enrollment to infrastructure density[E5]	0.05	0.05	0.25
Edu.governance impact education multiplier[E1]	0.01	0.01	0.5
Edu.governance impact education multiplier[E3]	0.05	0.05	0.5
Edu.governance impact education multiplier[E5]	0.14	0.05	0.5
Edu.initial adult population by education level adjustment	-0.05	-0.1	0.1
Edu.initial dropout rate by level[FEMALE, E0]	0.01	0.005	0.05
Edu.initial dropout rate by level[FEMALE, E1]	0.01	0	0.1
Edu.initial dropout rate by level[FEMALE, E2]	0.05	0.005	0.05
Edu.initial dropout rate by level[FEMALE, E3]	0.01	0	0.1
Edu.initial dropout rate by level[FEMALE, E4]	0.01	0.005	0.05
Edu.initial dropout rate by level[FEMALE, E5]	0.01	0.005	0.05
Edu.initial dropout rate by level[FEMALE, E6]	0.01	0.005	0.05
Edu.initial dropout rate by level[MALE, E0]	0.05	0.005	0.05
Edu.initial dropout rate by level[MALE, E1]	0.01	0	0.1
Edu.initial dropout rate by level[MALE, E2]	0.05	0.005	0.05
Edu.initial dropout rate by level[MALE, E3]	0.01	0	0.1
Edu.initial dropout rate by level[MALE, E4]	0.01	0.005	0.05
Edu.initial dropout rate by level[MALE, E5]	0.01	0.005	0.05
Edu.initial dropout rate by level[MALE, E6]	0.01	0.005	0.05
Edu.initial education gender bias[E1]	1.01	0.8	1.2
Edu.initial education gender bias[E3]	1.01	0.8	1.2
Edu.initial education gender bias[E5]	1.13	0.8	1.2
Edu.initial reference per capita education expenditure requirement[E1]	10567	1000	15000
Edu.initial reference per capita education expenditure requirement[E3]	13932	1000	25000
Edu.initial reference per capita education expenditure requirement[E5]	10632	2000	25000
Edu.initial to indicated public education enrollment capacity ratio[E1]	1.14	0.8	1.3
Edu.initial to indicated public education enrollment capacity ratio[E3]	0.91	0.9	1.1
Edu.initial to indicated public education enrollment capacity ratio[E5]	1.09	0.9	1.1
Edu.present education gender bias[E1]	1.00	0.8	1.2
Edu.present education gender bias[E3]	1.00	0.5	1.2
Edu.present education gender bias[E5]	1.20	0.8	1.2
Edu.previous grade graduation rate to enrollment multiplier[E1]	0.50	0.1	0.5
Edu.previous grade graduation rate to enrollment multiplier[E3]	0.21	0.1	0.5
Edu.previous grade graduation rate to enrollment multiplier[E5]	0.45	0.1	0.5
Edu.private education threshold poverty line ratio	20.07	2	30
Edu.proportion of population preferring public education	0.95	0.05	0.95
Edu.reference per capita education expenditure requirement relative change past[E1]	0.24	-1	1
Edu.reference per capita education expenditure requirement relative change past[E3]	0.64	-1	1

Parameter	Value	Minimum	Maximum
Edu.reference per capita education expenditure requirement relative change past[E5]	-0.06	-1	1
Edu.secondary gross to net enrollment ratio[FEMALE]	1.78	1	1.2
Edu.secondary gross to net enrollment ratio[MALE]	1.20	1	1.2
Edu.tertiary gross to net enrollment ratio[FEMALE]	1.00	1	1.2
Edu.tertiary gross to net enrollment ratio[MALE]	1.00	1	1.2
Edu.years of schooling by education level[FEMALE, E1]	3.28	3	5
Edu.years of schooling by education level[FEMALE, E2]	6.00	6	7
Edu.years of schooling by education level[FEMALE, E3]	10.43	8	11
Edu.years of schooling by education level[FEMALE, E4]	13.00	12	13
Edu.years of schooling by education level[FEMALE, E5]	15.00	14	15
Edu.years of schooling by education level[FEMALE, E6]	17.00	16	17
Edu.years of schooling by education level[MALE, E1]	4.16	3	5
Edu.years of schooling by education level[MALE, E2]	6.34	6	7
Edu.years of schooling by education level[MALE, E3]	11.00	8	11
Edu.years of schooling by education level[MALE, E4]	13.00	12	13
Edu.years of schooling by education level[MALE, E5]	15.00	14	15
Edu.years of schooling by education level[MALE, E6]	17.00	16	17
EmW.elasticity of waste generation to pc income	1.00	0	1
EmW.fossil fuel c emission factor[COAL]	29.20	22	29.2
EmW.fossil fuel c emission factor[GAS]	11.96	11.7	17.5
EmW.fossil fuel c emission factor[OIL]	15.00	15	21.1
EmW.initial per capita waste generation[rural]	0.50	0.5	20
EmW.initial per capita waste generation[urban]	13.39	0.5	20
EmW.present pm 25 abatement proportion	0.76	0	0.8
Emp.effect of social and market framework on employment gender gap	0.00	0	0.25
Emp.elasticity of agriculture land labor ratio to capital intensity[agr 1]	1.00	0.001	1
Emp.elasticity of agriculture land labor ratio to capital intensity[agr 2]	0.01	0.01	1
Emp.elasticity of agriculture land labor ratio to years of schooling[agr 1]	0.64	0.1	2
Emp.elasticity of agriculture land labor ratio to years of schooling[agr 2]	0.10	0.1	2
Emp.elasticity of capital labor ratio to employment to adult population ratio[agr 3]	4.78	0.05	5
Emp.elasticity of capital labor ratio to employment to adult population ratio[agr 4]	0.05	0.05	7
Emp.elasticity of capital labor ratio to employment to adult population ratio[agr 5]	0.05	0.05	5
Emp.elasticity of capital labor ratio to employment to adult population ratio[ind 1]	0.05	0.05	1.5
Emp.elasticity of capital labor ratio to employment to adult population ratio[ser 1]	0.14	0.05	1.2
Emp.elasticity of capital labor ratio to employment to adult population ratio[ser 2]	0.28	0.05	1.2
Emp.elasticity of capital labor ratio to years of schooling[agr 3]	1.57	0.05	5
Emp.elasticity of capital labor ratio to years of schooling[agr 4]	6.13	0.05	10
Emp.elasticity of capital labor ratio to years of schooling[agr 5]	0.05	0.05	5
Emp.elasticity of capital labor ratio to years of schooling[ind 1]	0.06	0.05	3
Emp.elasticity of capital labor ratio to years of schooling[ser 1]	0.65	0.05	1.5
Emp.elasticity of capital labor ratio to years of schooling[ser 2]	1.19	0.05	1.5

Parameter	Value	Minimum	Maximum
Emp.elasticity of labor force pressure on agriculture land labor ratio[agr 1]	0.00	-1.2	0
Emp.elasticity of labor force pressure on agriculture land labor ratio[agr 2]	-0.26	-1.2	0
Emp.employment gender gap adjustment time	10.00	1	10
Emp.initial agriculture land labor imbalance[agr 1]	0.86	0.8	1.2
Emp.initial agriculture land labor imbalance[agr 2]	1.50	0.8	1.5
Emp.initial capital labor imbalance[agr 3]	1.27	0.5	3
Emp.initial capital labor imbalance[agr 4]	5.07	0.5	10
Emp.initial capital labor imbalance[agr 5]	1.18	0.5	1.5
Emp.initial capital labor imbalance[ind 1]	1.09	0.5	1.5
Emp.initial capital labor imbalance[ser 1]	0.99	0.5	1.5
Emp.initial capital labor imbalance[ser 2]	0.91	0.5	1.5
Emp.potential change in capital labor ratio from change in capital cost[ind 1]	0.05	0	0.5
Emp.potential change in capital labor ratio from change in capital cost[ser 1]	0.00	0	0.1
Emp.potential change in capital labor ratio from change in capital cost[ser 2]	0.05	0	0.1
Emp.ratio employment gender gap to education gender gap	3.64	0.05	4
Emp.time to adjust employment level[agr 1]	1.00	1	5
Emp.time to adjust employment level[agr 2]	4.67	1	5
Emp.time to adjust employment level[agr 3]	2.26	1	7
Emp.time to adjust employment level[agr 4]	3.04	1	5
Emp.time to adjust employment level[agr 5]	7.41	1	10
Emp.time to adjust employment level[ind 1]	4.89	1	5
Emp.time to adjust employment level[ser 1]	1.09	1	5
Emp.time to adjust employment level[ser 2]	1.00	1	5
EnC.elasticity of access to electricity to education[rural]	1.00	0.1	1.5
EnC.elasticity of access to electricity to education[urban]	1.25	0.1	1.5
EnC.elasticity of access to electricity to income[rural]	0.50	0.1	1.5
EnC.elasticity of access to electricity to income[urban]	0.50	0.1	1.5
EnC.elasticity of access to electricity to supply demand balance[rural]	0.25	0.1	1.5
EnC.elasticity of access to electricity to supply demand balance[urban]	0.25	0.1	1.5
EnC.elasticity of electricity consumption to access[agr, ELE]	0.10	0.01	0.25
EnC.elasticity of electricity consumption to access[ind, ELE]	0.23	0.01	0.25
EnC.elasticity of electricity consumption to access[oth, ELE]	0.01	0.01	0.25
EnC.elasticity of electricity consumption to access[res, ELE]	0.03	0.025	0.5
EnC.elasticity of electricity consumption to access[ser, ELE]	0.16	0.025	0.5
EnC.elasticity of energy demand to average energy price[agr]	-0.19	-1	0
EnC.elasticity of energy demand to average energy price[ind]	-0.16	-1	0
EnC.elasticity of energy demand to average energy price[oth]	0.00	-1	0
EnC.elasticity of energy demand to average energy price[res]	-0.30	-1	0
EnC.elasticity of energy demand to average energy price[ser]	-0.05	-1	0
EnC.elasticity of energy demand to gdp[agr]	0.00	0	1
EnC.elasticity of energy demand to gdp[ind]	0.98	0	1
EnC.elasticity of energy demand to gdp[oth]	0.20	0	1
EnC.elasticity of energy demand to gdp[res]	0.00	0	1

Parameter	Value	Minimum	Maximum
EnC.elasticity of energy demand to gdp[ser]	0.00	0	1
EnC.elasticity of energy demand to global efficiency trend[agr]	0.00	-1	0
EnC.elasticity of energy demand to global efficiency trend[ind]	-0.26	-1	0
EnC.elasticity of energy demand to global efficiency trend[oth]	0.00	-1	0
EnC.elasticity of energy demand to global efficiency trend[res]	0.00	-1	0
EnC.elasticity of energy demand to global efficiency trend[ser]	0.00	-1	0
EnC.elasticity of energy shares to prices[agr, BIO]	-0.09	-1	0
EnC.elasticity of energy shares to prices[agr, COAL]	-0.04	-1	0
EnC.elasticity of energy shares to prices[agr, ELE]	-0.12	-1	0
EnC.elasticity of energy shares to prices[agr, GAS]	-0.16	-1	0
EnC.elasticity of energy shares to prices[agr, HEAT]	0.00	-1	0
EnC.elasticity of energy shares to prices[agr, OIL]	-0.36	-1	0
EnC.elasticity of energy shares to prices[ind, BIO]	-0.26	-1	0
EnC.elasticity of energy shares to prices[ind, COAL]	0.00	-1	0
EnC.elasticity of energy shares to prices[ind, ELE]	0.00	-1	0
EnC.elasticity of energy shares to prices[ind, GAS]	-0.08	-1	0
EnC.elasticity of energy shares to prices[ind, HEAT]	0.00	-1	0
EnC.elasticity of energy shares to prices[ind, OIL]	0.00	-1	0
EnC.elasticity of energy shares to prices[oth, BIO]	0.00	-1	0
EnC.elasticity of energy shares to prices[oth, COAL]	-0.07	-1	0
EnC.elasticity of energy shares to prices[oth, ELE]	0.00	-1	0
EnC.elasticity of energy shares to prices[oth, GAS]	-0.01	-1	0
EnC.elasticity of energy shares to prices[oth, HEAT]	-0.01	-1	0
EnC.elasticity of energy shares to prices[oth, OIL]	-0.01	-1	0
EnC.elasticity of energy shares to prices[res, BIO]	-0.20	-1	0
EnC.elasticity of energy shares to prices[res, COAL]	-0.03	-1	0
EnC.elasticity of energy shares to prices[res, ELE]	0.00	-1	0
EnC.elasticity of energy shares to prices[res, GAS]	0.00	-1	0
EnC.elasticity of energy shares to prices[res, HEAT]	-0.24	-1	0
EnC.elasticity of energy shares to prices[res, OIL]	-0.12	-1	0
EnC.elasticity of energy shares to prices[ser, BIO]	-0.91	-3	0
EnC.elasticity of energy shares to prices[ser, COAL]	-1.96	-3	0
EnC.elasticity of energy shares to prices[ser, ELE]	-1.17	-3	0
EnC.elasticity of energy shares to prices[ser, GAS]	-0.68	-3	0
EnC.elasticity of energy shares to prices[ser, HEAT]	0.00	-3	0
EnC.elasticity of energy shares to prices[ser, OIL]	-0.47	-3	0
EnC.elasticity of energy shares to prices[tra, BIO]	-0.26	-1	0
EnC.energy demand adjustment time[agr]	5.00	1	5
EnC.energy demand adjustment time[ind]	4.95	1	5
EnC.energy demand adjustment time[oth]	4.96	1	5
EnC.energy demand adjustment time[res]	5.00	1	5
EnC.energy demand adjustment time[ser]	4.99	1	5
EnC.energy technology suitability factor[agr, BIO]	0.03	-0.5	0.5
EnC.energy technology suitability factor[agr, COAL]	0.02	-0.5	0.5
EnC.energy technology suitability factor[agr, ELE]	0.04	-0.5	0.5
EnC.energy technology suitability factor[agr, GAS]	0.13	-0.5	0.5
EnC.energy technology suitability factor[agr, HEAT]	0.00	-0.5	0.5

Parameter	Value	Minimum	Maximum
EnC.energy technology suitability factor[agr, OIL]	-0.50	-0.5	0.5
EnC.energy technology suitability factor[ind, BIO]	0.10	-0.5	0.5
EnC.energy technology suitability factor[ind, COAL]	-0.09	-0.5	0.5
EnC.energy technology suitability factor[ind, ELE]	0.21	-0.5	0.5
EnC.energy technology suitability factor[ind, GAS]	0.18	-0.5	0.5
EnC.energy technology suitability factor[ind, HEAT]	0.03	-0.5	0.5
EnC.energy technology suitability factor[ind, OIL]	0.08	-0.5	0.5
EnC.energy technology suitability factor[oth, BIO]	-0.49	-0.5	0.5
EnC.energy technology suitability factor[oth, COAL]	-0.01	-0.5	0.5
EnC.energy technology suitability factor[oth, ELE]	0.00	-0.5	0.5
EnC.energy technology suitability factor[oth, GAS]	-0.01	-0.5	0.5
EnC.energy technology suitability factor[oth, HEAT]	-0.15	-0.5	0.5
EnC.energy technology suitability factor[oth, OIL]	-0.17	-0.5	0.5
EnC.energy technology suitability factor[res, BIO]	0.06	-0.5	0.5
EnC.energy technology suitability factor[res, COAL]	-0.01	-0.5	0.5
EnC.energy technology suitability factor[res, ELE]	-0.01	-0.5	0.5
EnC.energy technology suitability factor[res, GAS]	0.07	-0.5	0.5
EnC.energy technology suitability factor[res, HEAT]	-0.16	-0.5	0.5
EnC.energy technology suitability factor[res, OIL]	-0.02	-0.5	0.5
EnC.energy technology suitability factor[ser, BIO]	-0.44	-0.5	0.5
EnC.energy technology suitability factor[ser, COAL]	-0.47	-0.5	0.5
EnC.energy technology suitability factor[ser, ELE]	0.50	-0.5	0.5
EnC.energy technology suitability factor[ser, GAS]	0.48	-0.5	0.5
EnC.energy technology suitability factor[ser, HEAT]	0.03	-0.5	0.5
EnC.energy technology suitability factor[ser, OIL]	0.43	-0.5	0.5
EnC.energy technology suitability factor[tra, BIO]	-0.04	-0.5	0.5
EnC.initial energy demand trend[agr]	0.10	-0.1	0.1
EnC.initial energy demand trend[ind]	0.00	-0.1	0.1
EnC.initial energy demand trend[oth]	0.00	-0.1	0.1
EnC.initial energy demand trend[res]	0.10	-0.1	0.1
EnC.initial energy demand trend[ser]	0.10	-0.1	0.1
EnC.rural proportion of decentralized energy generation	0.60	0.1	1
EnC.rural urban electrification efficacy factor	0.50	0.2	1
EnC.time for energy consumption type substitution[agr]	3.42	1	10
EnC.time for energy consumption type substitution[ind]	6.23	1	10
EnC.time for energy consumption type substitution[oth]	3.05	1	10
EnC.time for energy consumption type substitution[res]	5.19	3	10
EnC.time for energy consumption type substitution[ser]	9.03	1	10
Fer.effectiveness of modern contraceptive methods	0.99	0.9	0.99
Fer.effectiveness of traditional contraceptive methods	0.89	0.65	0.95
Fer.elasticity of desired number of children to income	-0.32	-0.75	-0.1
Fer.elasticity of desired number of children to years of schooling	-0.36	-0.75	-0.1
Fer.elasticity of family planning access to health care expenditure	0.60	0	0.6
Fer.elasticity of family planning access to poverty	0.00	-1	0
Fer.elasticity of family planning demand to female average years of schooling	0.22	0.1	2
Fer.family planning cost relative change past	0.74	0	1
Fer.fertility probability multiplier	3.91	2	5

Parameter	Value	Minimum	Maximum
Fer.initial desired number of children per woman	1.04	1	8
Fer.initial family planning unit cost	28.47	5	100
Fer.minimum desired fertility rate	1.12	1	3
Fer.time for family planning expenditure implementation	3.00	0.5	3
Fin.initial total import trend	-0.06	-0.2	0.2
GDP.output shock peak value[ser 2]	0.00	-0.25	0
Hhs.elasticity of propensity to save to income	0.58	0.025	0.65
Hhs.elasticity of propensity to save to return on investment	0.03	0.025	1
Hhs.reference propensity to save lorenz	0.21	0.05	0.5
Hhs.reinvested proportion of capital remuneration	0.34	0.01	0.5
Hhs.saving threshold poverty line ratio	5.00	0.25	5
Hlt.elasticity of access to basic health care to governance	0.01	0.01	0.4
Hlt.elasticity of access to basic health care to infrastructure	0.16	0.005	0.2
Hlt.elasticity of access to basic health care to years of schooling	0.20	0.005	0.2
Hlt.elasticity of pm 25 exposure to pm 25 emissions	0.07	0.01	1
Hlt.elasticity of pm 25 exposure to urbanisation	0.01	0.01	0.25
Hlt.health saturation income to poverty line ratio	61.72	10	100
Hlt.initial per capita implemented health expenditure ratio to current	0.89	0.75	1.25
Hlt.initial real food poverty line to international poverty line ratio	10.00	0.5	10
Hlt.initial reference per capita health expenditure requirement	1693.50	1000	5000
Hlt.multiplier of malnutrition to food poverty	0.65	0.1	2
Hlt.multiplier of stunting to food poverty	0.65	0.1	2
Hlt.reference per capita health expenditure requirement relative change past	3.00	-1	3
Hlt.time for level of service and income to affect access to basic health care	5.21	1	10
Ifr.average infrastructure maintenance cost ratio[paved]	0.01	0.01	0.1
Ifr.average infrastructure maintenance cost ratio[rail]	0.02	0.01	0.1
Ifr.average infrastructure maintenance cost ratio[unpaved]	0.02	0.01	0.1
Ifr.initial infrastructure construction unit cost[paved]	2000000	500000	10000000
Ifr.initial infrastructure construction unit cost[rail]	5000000	500000	5000000
Ifr.initial infrastructure construction unit cost[unpaved]	800000	5000	100000
Inc.capital skew parameter	0.68	0	1
Inc.initial capital gini coefficient	0.33	0.2	0.8
Inc.initial indicated salaries and wages gini coefficient	0.73	0.1	0.8
Inc.initial minimum salary relative to average salary	0.33	0.1	0.5
Inc.initial proportion of formally unemployed receiving salaries and wages	0.05	0.05	0.8
Inc.percentile proficiency difference in years of schooling equivalent	0.03	0.01	0.05
Inc.present minimum salary relative to average salary	0.31	0.1	0.5
Inc.present proportion of formally unemployed receiving salaries and wages	0.06	0.05	0.8
Inc.proportion of adult population with partial employment	0.11	0.05	0.5
Inc.salaries and wages lorenz curve adjustment time	19.82	5	20
Inc.salaries and wages skew parameter	0.75	0	1
Inc.time for capital distribution adjustment	15.41	10	30
Ind.elasticity of productivity to education industry[ind 1]	0.70	0.2	0.6
Ind.elasticity of productivity to electrification industry[ind 1]	0.10	0.025	0.1

Parameter	Value	Minimum	Maximum
Ind.elasticity of productivity to female participation industry[ind 1]	0.40	0.05	0.4
Ind.elasticity of productivity to governance industry[ind 1]	0.40	0.05	0.4
Ind.elasticity of productivity to inflation industry[ind 1]	-0.01	-0.1	-0.01
Ind.elasticity of productivity to infrastructure density industry[ind 1]	0.10	0.025	0.1
Ind.elasticity of productivity to life expectancy industry[ind 1]	0.40	0.1	0.4
Ind.elasticity of productivity to trade industry[ind 1]	0.05	0.02	0.2
Ind.indicated to actual initial industry productivity ratio[ind 1]	1.05	0.95	1.05
Ind.industry capital elasticity[ind 1]	0.60	0.25	0.6
Ind.industry productivity adjustment time[ind 1]	3.00	1	3
Inv.elasticity of investment shares to return on investment[agr 1]	0.01	0.01	2
Inv.elasticity of investment shares to return on investment[agr 2]	0.01	0.01	2
Inv.elasticity of investment shares to return on investment[agr 3]	0.35	0.01	2
Inv.elasticity of investment shares to return on investment[agr 4]	2.20	0.1	4
Inv.elasticity of investment shares to return on investment[agr 5]	0.29	0.1	2
Inv.elasticity of investment shares to return on investment[ind 1]	2.00	0.05	0.25
Inv.elasticity of investment shares to return on investment[ser 1]	0.31	0.05	0.25
Inv.elasticity of investment shares to return on investment[ser 2]	0.00	0.05	0.25
Inv.initial investment shares bias[agr 1]	0.40	-1	0.2
Inv.initial investment shares bias[agr 2]	0.07	-1	0.2
Inv.initial investment shares bias[agr 3]	-0.50	-1	0.2
Inv.initial investment shares bias[agr 4]	-0.23	-1	0.2
Inv.initial investment shares bias[agr 5]	-0.03	-1	0.2
Inv.initial investment shares bias[ind 1]	0.23	-0.2	0.2
Inv.initial investment shares bias[ser 1]	0.50	-0.2	0.2
Inv.initial investment shares bias[ser 2]	0.00	-0.2	0.2
Lnd.elasticity of agriculture land demand to labor force availability[agr 1]	0.42	0.01	1
Lnd.elasticity of agriculture land demand to labor force availability[agr 2]	1.78	0.01	2
Lnd.elasticity of agriculture land demand to return on investment[agr 1]	1.18	0.1	2
Lnd.elasticity of agriculture land demand to return on investment[agr 2]	1.28	0.1	3
Lnd.elasticity of land protection effectiveness to governance	0.77	0.1	1
Lnd.elasticity of pasture land demand to capital per hectare	-0.43	-1	-0.05
Lnd.forest natural regrowth rate	0.00	0	0.05
Lnd.forest share in agriculture land increase[agr 1]	0.55	0	1
Lnd.forest share in agriculture land increase[agr 2]	0.23	0	1
Lnd.initial agriculture land demand to agriculture land ratio[agr 1]	0.83	0.75	1.25
Lnd.initial agriculture land demand to agriculture land ratio[agr 2]	1.09	0.75	1.25
Lnd.proportion of protected forest land under controlled production	0.25	0	0.25
Lnd.time to convert to agriculture land	2.98	1	5
Lnd.time to perceive change in agriculture return on investment[agr 1]	2.88	1	5
Lnd.time to perceive change in agriculture return on investment[agr 2]	1.00	1	5
Mat.average pasture yield	8.70	1	20
Mat.elasticity of biomass consumption to pc gdp	0.20	0.2	2
Mat.elasticity of fossil fuel production to domestic demand[COAL]	2.28	0	3
Mat.elasticity of fossil fuel production to domestic demand[GAS]	0.00	0	1
Mat.elasticity of fossil fuel production to domestic demand[OIL]	0.10	0	1
Mat.elasticity of fossil fuel production to global demand[COAL]	0.50	0	1

Parameter	Value	Minimum	Maximum
Mat.elasticity of fossil fuel production to global demand[GAS]	0.50	0	1
Mat.elasticity of fossil fuel production to global demand[OIL]	0.50	0	1
Mat.elasticity of informal forest biomass extraction to energy consumption	0.80	0	1
Mat.elasticity of metal ores consumption to pc gdp	0.20	0.2	2
Mat.elasticity of non metallic materials consumption to pc gdp	0.20	0.2	2
Mat.elasticity of pasture use to livestock density	0.33	0.25	1
Mat.initial informal forest biomass extraction proportion	0.00	0	0.005
Mat.initial proportion of pasture yield used	0.90	0.1	1
Mat.proportion of forest biomass used	0.64	0.1	0.9
Mat.proportion of forest sustainably harvested	0.08	0	1
Mat.tonnes of wood per cubic meter	0.47	0	2
Mor.initial mortality adjustment by age group[AGE 0]	0.40	0.1	2
Mor.initial mortality adjustment by age group[AGE 15]	1.00	0.1	2
Mor.initial mortality adjustment by age group[AGE 30]	1.00	0.1	2
Mor.initial mortality adjustment by age group[AGE 50]	1.00	0.1	2
Mor.initial mortality adjustment by age group[AGE 5]	1.00	0.01	5
Mor.initial mortality adjustment by age group[AGE 70]	1.00	0.1	10
Mor.initial mortality adjustment by age group[AGE 95]	1.00	0.5	1.5
Mor.initial mortality adjustment by cause[neonatal]	1.00	0.5	4
Mor.initial mortality adjustment by gender[FEMALE]	1.07	0.9	1.1
Mor.initial mortality adjustment by gender[MALE]	1.08	0.9	1.1
Mor.initial perceived to intial actual real pc gdp ratio	1.04	0.9	1.1
Mor.mortality change adjustment by age group[AGE 0]	1.50	0.1	2
Mor.mortality change adjustment by age group[AGE 15]	1.00	0.1	2
Mor.mortality change adjustment by age group[AGE 30]	1.00	0.1	2
Mor.mortality change adjustment by age group[AGE 50]	1.00	0.1	2
Mor.mortality change adjustment by age group[AGE 5]	1.00	0.01	5
Mor.mortality change adjustment by age group[AGE 70]	1.00	0.0001	2
Mor.mortality change adjustment by age group[AGE 95]	1.00	0.05	1.5
Mor.mortality change adjustment by gender[FEMALE]	0.70	0.1	2
Mor.mortality change adjustment by gender[MALE]	1.05	0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[aids]	-0.10	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[cardiovascular]	0.79	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[diabetes]	0.33	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[diarrhoeal]	-0.50	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[maternal]	0.60	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[neonatal]	1.50	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[neoplasms]	-0.07	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[nutritional]	-0.50	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[other]	-0.26	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[parasitic and vector]	1.05	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[respiratory]	0.54	-0.5	1.5

Parameter	Value	Minimum	Maximum
Mor.multiplier for elasticity of death rates to income by cause[road]	0.75	-0.5	1.5
Mor.multiplier for elasticity of death rates to income by cause[violence]	0.93	-0.5	1.5
Mor.reference elasticity of death rates to education	-0.05	-1	-0.05
Mor.reference elasticity of death rates to health expenditure	-1.00	-1	-0.05
Mor.reference elasticity of death rates to income	-0.72	-1	-0.03
Mor.reference elasticity of death rates to nourishment	-0.23	-1	-0.05
PES.elasticity of crop residues use for energy to energy consumption	0.17	0	1
PES.elasticity of manure use to energy consumption	0.12	0	1
PES.elasticity of proportion of agriculture production used for energy to energy consumption	0.66	0	1
PES.elasticity of proportion of biomass used for energy to energy consumption	0.13	0	1
PES.initial proportion of crop residues removed used for energy	0.00	0	0.95
PES.initial proportion of forest biomass used for energy	0.54	0.05	0.9
PES.initial proportion of manure used for energy	0.00	0	1
Pop.female share of migration	0.50	0.05	0.95
Pop.migrants age distribution deviation	13.68	5	100
Pop.migrants age distribution mean	24.56	0	60
Pov.education access threshold poverty line ratio	0.65	0.25	2
Pov.households second income as share of average deviation	42.29	5	50
Pov.households second income as share of average mean	14.11	0	100
Pov.initial relative direct tax pressure distribution deviation	25.12	5	50
Pov.initial relative direct tax pressure distribution mean	92.02	0	100
Pov.initial subsidies and transfers distribution deviation	23.81	5	50
Pov.initial subsidies and transfers distribution mean	40.92	10	80
Pov.national poverty line adjustment factor	1.01	0.5	2
Pov.present relative direct tax pressure distribution deviation	29.81	5	50
Pov.present relative direct tax pressure distribution mean	87.73	0	100
Pov.present subsidies and transfers distribution deviation	31.13	5	50
Pov.present subsidies and transfers distribution mean	33.34	10	80
Pov.time for income to affect purchasing power	3.00	1	3
Ser.elasticity of productivity to education services[ser 1]	0.20	0.2	0.6
Ser.elasticity of productivity to education services[ser 2]	0.20	0.2	0.6
Ser.elasticity of productivity to electrification services[ser 1]	0.04	0.025	0.1
Ser.elasticity of productivity to electrification services[ser 2]	0.03	0.025	0.1
Ser.elasticity of productivity to female participation services[ser 1]	0.26	0.05	0.3
Ser.elasticity of productivity to female participation services[ser 2]	0.05	0.05	0.3
Ser.elasticity of productivity to governance services[ser 1]	0.40	0.05	0.4
Ser.elasticity of productivity to governance services[ser 2]	0.10	0.05	0.4
Ser.elasticity of productivity to inflation services[ser 1]	-0.01	-0.1	-0.01
Ser.elasticity of productivity to inflation services[ser 2]	-0.01	-0.1	-0.01
Ser.elasticity of productivity to infrastructure density services[ser 1]	0.10	0.025	0.1
Ser.elasticity of productivity to infrastructure density services[ser 2]	0.03	0.025	0.1
Ser.elasticity of productivity to life expectancy services[ser 1]	0.10	0.1	0.4
Ser.elasticity of productivity to life expectancy services[ser 2]	0.10	0.1	0.4
Ser.elasticity of productivity to trade services[ser 1]	0.03	0.025	0.2
Ser.elasticity of productivity to trade services[ser 2]	0.10	0.025	0.2
Ser.indicated to actual initial services productivity ratio[ser 1]	1.05	0.95	1.05

Parameter	Value	Minimum	Maximum
Ser.indicated to actual initial services productivity ratio[ser 2]	1.01	0.95	1.05
Ser.services capital elasticity[ser 1]	0.25	0.25	0.6
Ser.services capital elasticity[ser 2]	0.00	0.25	0.6
Ser.services productivity adjustment time[ser 1]	3.00	1	3
Ser.services productivity adjustment time[ser 2]	1.00	1	3
Sln.base proportion of nitrogen fixing crops[crop 1]	0.05	0.001	0.2
Sln.crop nutrient uptake proportion adjustment factor to local crop mix[crop 1]	0.30	0.3	3
Sln.crop nutrient uptake proportion adjustment factor to local crop mix[crop 2]	0.57	0.3	3
Sln.elasticity of manure application to energy use	0.00	-5	0
Sln.harvest index[crop 1]	0.27	0.2	0.8
Sln.harvest index[crop 2]	0.49	0.4	0.6
Sln.initial manure crop application proportion	0.10	0	0.15
Sln.manure crop application proportion relative change past	-0.76	-1	0
Sln.proportion of crop residues removed	0.45	0.1	0.8
Sln.proportion of nitrogen fixing crops in sustainable agriculture[crop 1]	0.16	0.001	0.5
Sln.reference biological fixation per tonne[crop 1]	0.00	0.0001	0.08
Sln.reference rainfall	19.03	1	100
Sln.relative fertilizer intensity by crop[crop 1]	1.50	1	1.4
Sln.relative fertilizer intensity by crop[crop 2]	1.50	1.4	2
Veh.elasticity of km per vehicle per year to income[commercial]	-3.00	-1	1
Veh.elasticity of km per vehicle per year to income[passenger]	-1.32	-1	1
Veh.elasticity of km per vehicle per year to roads density[commercial]	0.05	-1	1
Veh.elasticity of km per vehicle per year to roads density[passenger]	0.05	-1	1
Veh.elasticity of vehicles per person to income[commercial]	3.00	1.2	1.5
Veh.elasticity of vehicles per person to income[passenger]	1.50	1.2	1.5
Veh.elasticity of vehicles to paved roads density[commercial]	3.00	0.1	1.5
Veh.elasticity of vehicles to paved roads density[passenger]	1.44	0.1	1.5
Veh.initial average km per vehicle per year[commercial]	39000	30000	40000
Veh.initial average km per vehicle per year[passenger]	16500	10000	20000
Veh.initial passenger to commercial vehicle fuel efficiency ratio	1.00	1	3
Veh.initial proportion of new vehicles electric[passenger]	0.00	0	0.1
Veh.initial total vehicles average fuel efficiency	11.81	5	15
Veh.pm 25 emission from tire and break wear and road dust	0.02	0.015	0.0301
Veh.pm 25 emission per liter of fuel	0.80	0.7	1.9
Veh.pm emissions reduction to fuel efficiency multiplier	-5.68	-6	-2.5
Veh.present proportion of new vehicles electric[passenger]	0.01	0	0.2
Veh.vehicle gap adjustment time[commercial]	4.68	1	5
Veh.vehicle gap adjustment time[passenger]	1.90	1	5
Veh.vehicles fuel efficiency yearly increase[commercial]	0.19	0	0.3
Veh.vehicles fuel efficiency yearly increase[passenger]	0.28	0	0.3
WaS.average life of safely managed sanitation facility[rural]	30.00	10	30
WaS.average life of safely managed sanitation facility[urban]	30.00	10	30
WaS.average life of safely managed water source[rural]	32.83	20	40
WaS.average life of safely managed water source[urban]	40.00	20	40
WaS.elasticity of water access to water scarcity[rural]	0.84	0.1	0.9
WaS.elasticity of water access to water scarcity[urban]	0.82	0.1	0.9

Parameter	Value	Minimum	Maximum
WaS.initial safely managed sanitation facility unit cost[rural]	2000	100	3000
WaS.initial safely managed sanitation facility unit cost[urban]	1879	100	3000
WaS.initial safely managed water source unit cost[rural]	899	50	1000
WaS.initial safely managed water source unit cost[urban]	807	50	1000
WaS.safely managed sanitation facility unit cost relative change past[rural]	-0.25	-1	0.25
WaS.safely managed sanitation facility unit cost relative change past[urban]	-0.78	-1	0.25
WaS.safely managed water source cost relative change past[rural]	-0.47	-0.5	0.25
WaS.safely managed water source cost relative change past[urban]	-0.31	-1	0.25
WaW.elasticity of agriculture water withdrawal to relative global water efficiency	0.00	-2	1
WaW.elasticity of domestic and municipal water withdrawal to access to safely managed water source and sanitation facility	1.00	0.1	1
WaW.elasticity of domestic and municipal water withdrawal to relative global water efficiency	-0.91	-2	1
WaW.elasticity of industry water demand to relative global water efficiency	-2.67	-3	1
WaW.elasticity of pc water demand to income	0.10	0.1	1