Annex: MAGNET model documentation

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1. Introduction to Computable General Equilibrium models

A Computable General Equilibrium (CGE) model is a system of equations that describes an economy as a whole and the interactions among its parts. It is based on equations derived directly from economic theory, combining microeconomic and macroeconomic theory. The equations may describe producers' supply or consumer demand, or be standard macroeconomic identities such as Gross Domestic Product = Consumption (C) + Investments (I) + Government expenditures (G) + Exports (E) – Imports (M). A CGE model includes exogenous and endogenous variables and market-clearing constraints. All the equations in the model are solved simultaneously to find an economy-wide equilibrium in which, at some set of prices, the quantities of supply and demand are equal in every market. To conduct experiments with a CGE model, the economist changes one or more exogenous variables and resolves the CGE model to find new values for the endogenous variables. The economist observes how the exogenous change, or "economic shock", affect the market equilibrium, and draws conclusions about the economic concern under study – be it a rise in the price of specific commodities or the use of production factors such as land, capital, or labor.

A key feature of CGE models lies in their representation of the whole economy, even if at times in a very stylized and simplified way. A CGE model describes production decision in two or more industries (or sectors) and includes demand of all goods and services in the economy. A CGE model describes how changes in the demand and supply for a good X can lead to changes in employment and wages and therefore in households' income. It parallelly describes changes in prices for other goods and services in the economy that compete with good X in consumer demand. A CGE also includes all sources of demand, not only from producers and private households but also from other economic agents – the government, investors, and foreign markets. Because a CGE model depicts all the microeconomic activity in an economy, the summation of these activities describes the macroeconomic behavior of an economy, including its gross domestic product (GDP), aggregate savings and investment, the balance of trade, and, in some CGE models, the government fiscal deficit ort surplus.

Running an experiment with a CGE model involves comparing a "baseline" scenario to one or more "test scenarios" to understand how specific changes, like a new policy or environmental event, could impact the economy across a given future timeframe. First, the baseline scenario is created. This serves as a reference point and represents how the economy is expected to evolve over time under current conditions, without any major new changes or interventions. The baseline includes assumptions about factors like population growth, technological progress, and current policies. It's like setting up a virtual version of the economy as it exists today and projecting how it would naturally develop over time.

Next, a test scenario is introduced to simulate the effect of a specific change or shock. For example, you might want to analyze the impact of introducing a carbon tax, reducing land productivity due to soil degradation, or implementing a new trade policy. The model is adjusted to reflect this change by modifying the relevant parameters, such as tax rates or productivity levels.

The CGE model then runs simulations for both the baseline and the test scenarios. These simulations calculate how the economy responds, taking into account interactions between industries, households, governments, and other economic agents. The model outputs data for variables like GDP, trade, production, prices, and income distribution. Finally, the results are compared. The difference between the baseline and the test scenario shows the impact of the change being studied. For instance, if a carbon tax is implemented, the comparison might reveal changes in energy prices, shifts in production from fossil fuels to renewables, or effects on household consumption. This process helps policymakers and researchers understand the potential consequences of decisions or events in a systematic and data-driven way.

2. The core of the MAGNET model: The GTAP model and database

The MAGNET model builds upon the The Global Trade Analysis Project (GTAP) database and model which constituted foundational tools used in economic research, particularly for analyzing global trade, policy impacts, and economic interdependencies. The GTAP database gathers comprehensive, consistent, and detailed global economic data, primarily for use in computable general equilibrium (CGE) modeling. It covers multiple countries and regions (the current version 11 covers 141 countries and 19 composite regions), and includes data on global bilateral trade, production, consumption, and intermediate production inputs. It contains a detailed sectoral breakdown for agriculture, manufacturing, services, and energy. The database is periodically updated to include new data and reflect changes in global economic structures. The GTAP database is constituted by country-specific Social Accounting Matrixes (SAM) i.e. analytical frameworks capturing the economic transactions and linkages within an economy during a specific period. A Social Accounting Matrix (SAM) is a comprehensive representation of the flow of income and expenditures among different economic agents, including households, businesses, government, and the rest of the world. Structured as a square matrix, a SAM records these flows in monetary terms, ensuring that for each account (row), income equals expenditure (column). The SAM integrates data from national accounts, input-output tables, and other economic surveys, allowing detailed insights into production, income distribution, and consumption patterns.

The GTAP model is designed to study how changes in policies, such as trade agreements, taxes, or environmental regulations, can affect economies around the world. Think of it as a virtual representation of the global economy, where countries and industries are connected through trade, investment, and consumption. At its core, the GTAP model works by simulating how resources like labor, capital, and raw materials are allocated among industries and regions. It assumes that businesses and consumers respond to changes in prices and policies by adjusting their production and consumption patterns. For example, if a country imposes a tax on imported goods, the model can predict how that might affect domestic industries, consumer prices, and trade flows. By combining the GTAP database with mathematical equations, the model calculates how economies might adjust to specific scenarios, such as a new free trade agreement or a carbon tax. The results help researchers and policymakers understand the potential impacts on economic growth, employment, trade balances, and even environmental outcomes like greenhouse gas emissions. Even though the GTAP model is based on economic theories like supply and demand, it is flexible enough to include additional factors, such as government policies, resource constraints, and international markets. For additional information visit www.gtap.agecon.purdue.edu

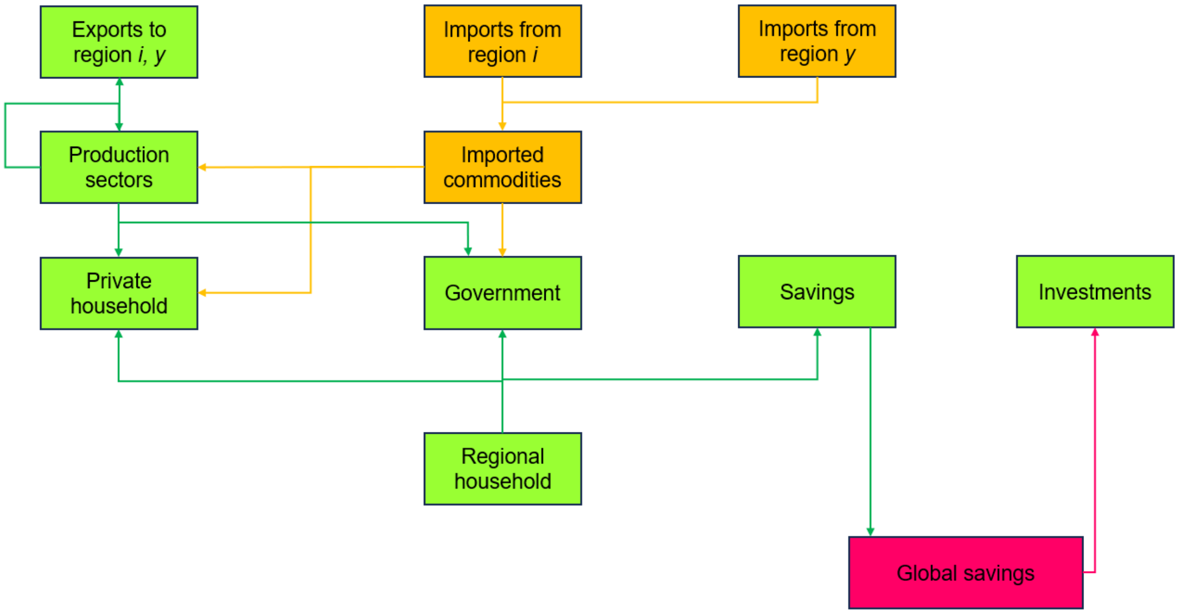


Figure 1. A simplified representation of the main economic connections in the GTAP model.

3. The MAGNET model

MAGNET is a multi-regional, multi-sectoral applied computable general equilibrium (CGE) model. It is an advanced recursive dynamic version of the Global Trade Analysis Project (GTAP) model (Corong et al., 2017), which has been extended to allow integrated assessments focusing mainly on food and biomass production. As a CGE model, MAGNET solves through adjusting prices such that all markets for factors (land, labor, capital, natural resources) and commodities (good and services) simultaneously clear. Producers (one for each sector-region combination) respond to changing prices for inputs (factors and intermediates) based on profit maximization. With constant returns to scale production, producers operate under zero-profit conditions. Representative private households (one for each region) respond to changing incomes earned with factor sales and changing prices of commodities for consumption based on utility maximization limited by the household's income constraint. International trade flows are modelled bilaterally between all regions with regional sourcing of imports governed by the Armington assumption which allows two-way trade flows. Being "dynamic", MAGNET captures dynamic adjustments over time, such as capital accumulation, technological progress, or demographic changes, providing a more comprehensive understanding of economic trajectories and their impact on agents. An overview of the structure of MAGNET with the interactions between production, trade, and consumption is provided in Figure 2 below.

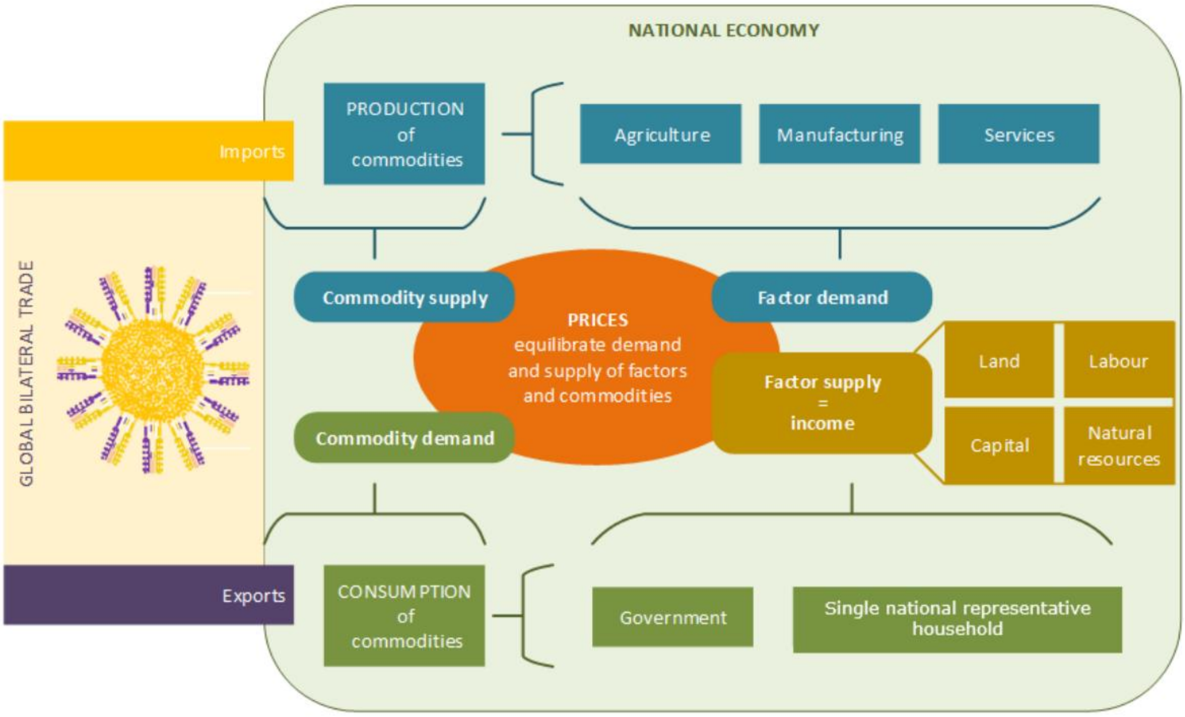


Figure 2. Schematic outline of the structure of MAGNET and the circular flow of money and commodities through the global economy.

A distinguishing feature of MAGNET is its modular structure, allowing the model to be easily tailored to specific research questions, regions, and products of interest. As a global CGE model MAGNET covers the entire global economy, with extensions adding detail on food and biomass production and use not available from other CGE models. Modules relevant for the current study are the flexible production trees (allowing for more substitution possibilities in production inputs than in the standard GTAP model), endogenous land supply (allowing land areas to expand and contract depending on demand), flexible land allocation (governing the movement of sluggish land across sectors depending on the ease of switching between different types of land use), purchasing power adjusted demand function (adjusting income elasticities in baseline projections to attain a more plausible pattern in food demand when incomes rise substantially), and segmented factor markets (capturing diverging labor and capital price developments in agricultural and non-agricultural sectors). MAGNET expands the global coverage of the GTAP model and database by integrating additional sectors and commodities across countries. The standard version of MAGNET includes 160 regions and 130 sectors, producing 155 commodities. Additional information about the MAGNET model is available at www.magnet-model.eu.

3.1. Land modelling

A key MAGNET feature for the current study is the improved representation of land. Understanding how land use changes over time and with different policies is not only a concern for economic analyses, but it also features prominently in discussions on climate change and biodiversity loss.

Most CGE models do not account for possible changes in the total amount of agricultural land. In contrast, the MAGNET model uses a land supply curve to describe the relationship between average real agricultural land rent and the area of land in a country that is used for agriculture. This allows to quantify the direct effects of land-related shocks, such as soil degradation, on the global economy, enabling a consistent link between environmental shocks and economy-wide impacts in the future.

In the standard GTAP model, land is a primary production factor, and the quantity of land is expressed as the value added of land in constant prices. The total regional supply of land in constant prices is an exogenous variable in the model. In MAGNET, land supply is endogenous and is determined by a land supply curve, i.e., a relationship is defined between the real agricultural land rent and agricultural land area in km2. To do this, land area in km2 is added to the database.

In detail, the total agricultural land supply is modelled using a land supply curve which specifies the relation between land supply and a land rental rate (see Figure 3). The general idea underlying the land supply curve specification is that the most productive land is first taken into production. The potential for bringing additional land into agriculture production is limited to the maximum potentially available land. That maximum is defined based on regional data regarding land use (e.g. arable land, forestry, pasture areas, fallow land etc.) and is arranged in order of diminishing productivity. Land rents and yields are related in that increasing yields result in lower land rents and vice versa, which gives a land supply curve in which the total amount of land used in production is an increasing function of land rent.

If the gap between the potentially available agricultural land and the land used in the agricultural sector is large, an increase in demand for agricultural land will lead to land being converted to agricultural land and a modest increase in rental rates to compensate for the cost to put this land into production (see left part of Figure 3). Such a situation is illustrated by points situated on the left, flat part of the land supply curve. However, once nearly all agricultural land is in use, an increase in demand for agricultural land will mainly lead to large increases in land rental rates (land becomes scarce, see right part of Figure 3). In this case, land conversion is difficult to achieve and therefore the elasticity of land supply with respect to land rental rates is low as well. Additional land is brought into production until the point where the benefit of the last (additional) hectare of land (hence marginal benefit), measured by its marginal value, equals the cost of making an extra hectare of land suitable for cultivation.

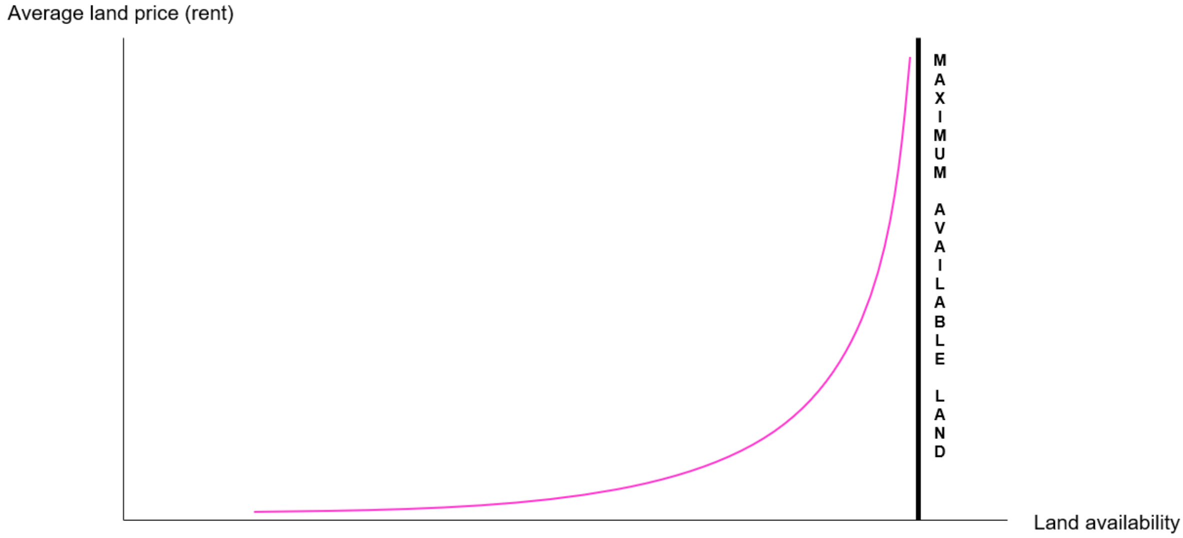


Figure 3. Land supply curve in the MAGNET model.

The area of land that is potentially suitable and available for agricultural expansion is estimated by the team of the IMAGE integrated assessment model (Stehfest et al., 2014). The assessment focuses on the availability and suitability for agricultural land. The analysis is performed using gridded data with a spatial resolution of 5 arc minutes. It takes into account biophysical (environmental) and anthropogenic (human) exclusions factors, or reasons, why the land is unsuitable or unavailable for agricultural expansion. The biophysical factors taken into account are marginal yields, steep slopes, non-soils and permafrost based on various data sources and assumptions. The anthropogenic factors taken into account are built-up areas, roads, current agriculture, forestry, protected areas and other anthropogenically used land.

3.2. Model Baseline

The baseline scenario of the MAGNET model, used as a reference for comparing the results of various simulations, covers the period from 2017 to 2050, divided into 5-years periods. Like many CGE models, baseline parameters implemented in the model are exogenous, meaning they are determined outside the model and remain unaffected by the model's simulation results. As in most of CGE baselines, key factors shaping the economy over time are technological growth, representing the expected improvement in production technology over the years, and population growth, reflecting demographic trends in different countries. The key resource for the MAGNET baseline are the Shared Socio-Economic Pathways (SSPs) recently updated to version 3.0 (see https://data.ece.iiasa.ac.at/ssp). The SSP2 that is employed in the project is usually described as the 'business-as-usual' as it presumes medium GDP and population growth in line with historical developments. On top of the population and GDP paths, additional growth parameters are implemented for labour supply (working force availability), capital stocks, natural resources, agricultural and land productivity. Together, these factors provide a foundation for understanding how the economy might evolve under current conditions, without additional shocks or policy changes. The baseline setup does not include any particular climate shocks or climate pathways (i.e. Representative Concentration Pathways) apart from the Ecosystem Service related shocks that are prepared in WP2.

4. MAGNET in the BiROFin project

4.1. Simulating soil erosion in the MAGNET model

4.1.1. Setting

In MAGNET, land productivity reflects how efficiently land contributes to production, particularly in agriculture. To simulate soil degradation, we reduce land productivity by adjusting a variable in the model that represents technical change. This variable typically captures improvements or declines in productivity due to technological advancements or other factors. By applying a "negative shock" to this variable, we mimic the impact of soil degradation, such as reduced crop yields or less efficient use of farmland. The model then calculates how this change affects the entire economy, showing shifts in production, trade, prices, and incomes as industries and consumers adapt to the reduced land productivity. As land productivity declines, more land is needed to produce the same amount of output. This increased demand for land can drive up land prices, especially in regions where land is scarce. However, the possibility of substituting land with fertilizers is key in determining the magnitude of impacts observed across the economy. Nonetheless, the cost of producing goods that rely on land, such as food and other biomass products, is likely to rise as higher production costs for producers may lead to an overall increase in the prices of these goods. The rate of land productivity loss linked to the degradation of soils is directly derived from the research performed in WP2 and is integrated into MAGNET as a productivity shock, implemented across different years towards 2050. Shocks to land productivity are not specific to individual crops and impact all crop production that relies on land. However, crops that are more land-intensive are likely to be disproportionately affected, as the increase in land prices could lead to a greater rise in production costs.

4.1.2. Analysis

The degradation of soils is considered to have global repercussions as regions producing agricultural goods are likely to be affected. Impacts across regions are however heterogeneous, as regions largely relying on agricultural production or agricultural land use are likely to be more affected than non-agricultural, land-scarce regions. The effect of a decline in land productivity is reflected in an increase in producer prices and a reduction of agricultural production for the land-dependent agricultural sectors. This has further repercussions on decline of domestic supply and exports, possibly rising prices. To meet demand, a higher use of inputs is necessary for compensating the decrease in productivity. Input use may increase for land, fertilizers, or both, according to prices and availability of such inputs in a specific region over time. The final effects on agricultural production in land-dependent sectors depends on the ability of regions to substitute between such inputs and therefore can be both positive and negative. The second order – macroeconomic effects also depend on the substitutability assumption as well as on the importance of land-dependent sectors and regions in the economy. In case of higher dependence and substitution, notable amount of resources move from other industries to compensate for productivity loss in agriculture with detrimental impacts on GDP and incomes of urban households. An illustration of the analysis of the impact of pollination loss in the MAGNET model is provided in figure 4 below.

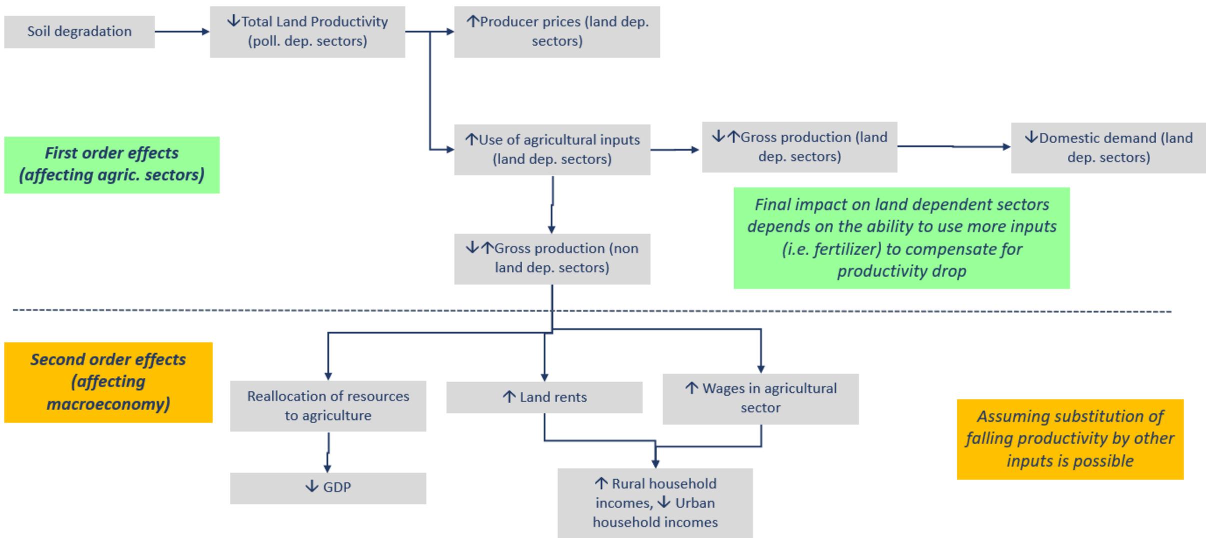


Figure 4. Impact of soil degradation in the MAGNET model.

4.2. Simulating the loss of pollinators in the MAGNET model

4.2.1. Setting

In the MAGNET model, the economy is represented as an interconnected system where resources like labor, land, and technology contribute to production. Crop productivity measures how efficiently crops are grown, i.e. the ratio between the amount of inputs needed for production and the produced output. Pollinators play a crucial role in enhancing the productivity of many crops across countries. To simulate the loss of pollinators, we reduce crop productivity in the model by adjusting a variable that represents technical change. This variable typically accounts for changes in production efficiency, such as improvements from technology or, in this case, declines due to pollinator loss. By applying a "negative shock" to this variable, we replicate the reduced yields and declined efficiency of different crop productions associated with fewer pollinators. The model then recalculates the economy's response to this change. It shows how reduced crop productivity affects agricultural output, increases production costs, and potentially raises prices for food and other products reliant on these crops. As for the soil erosion shock, the rates of productivity loss linked to the reduction in pollinators (see work package 2) are integrated into MAGNET as a productivity shock, implemented across different years towards 2050. This allows closely replicating biological patterns into a value-based framework, key for quantifying economic impacts. Losses in productivity are simulated for 9 different crops inclusive of cereals and horticulture commodities.

4.2.2. Analysis

The loss of pollination ability is considered systemic and global, given that more than three quarters of the leading global food crop types are affected. At the same time, across different agricultural sectors, these impacts vary as some crops rely more on pollination than others. Across the economy, the interpretation of impacts is similar to the case of soil degradation (figure 4). The effect of a decline in agricultural productivity is reflected in an increase in producer prices and a reduction of agricultural production for the pollination-dependent agricultural sectors. This has further repercussions on the decline of domestic supply and exports. To satisfy consumer demand (which is inelastic in the case of food), higher use of agricultural inputs must compensate for the drop of productivity. The final effects on agricultural production in pollinator- dependent sectors depends on this substitution ability and therefore can be both positive or negative. The second-order macroeconomic effects also depend on this assumption as well as on the importance of pollinator-dependent sectors in the economy. In case of higher dependence and substitution, a notable amount of resources move from other industries to compensate for productivity loss in agriculture, with detrimental impacts on GDP and incomes of urban households. An illustration of the analysis of the impact of pollination loss in the MAGNET model is provided in Figure 5 below.

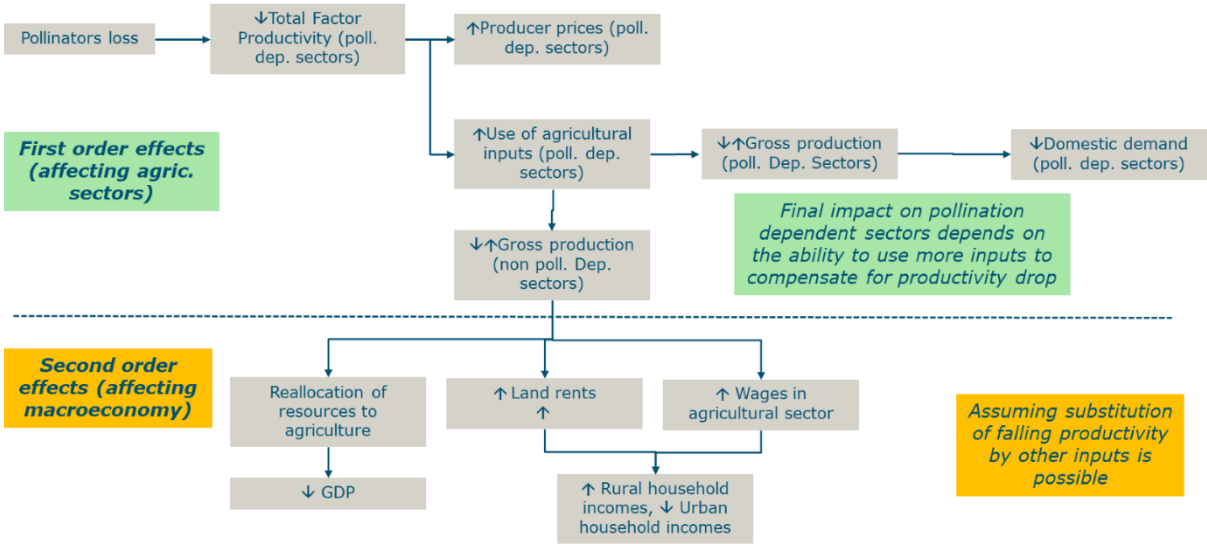


Figure 5. Impact of the loss of pollinators in the MAGNET model.

4.3. Simulating a "half earth scenario" in the MAGNET model

4.3.1. Setting

The half-earth scenario was devised in Kok et al. (2020) and restricts the future possible expansion of agricultural land use so that globally in total 50% of the land area is protected, giving priority to biodiversity rich areas. Intensive agriculture is not forcibly removed, but room for expansion is severely limited. The implementation of the half earth scenario in the MAGNET model is done by a so-called shifting of the asymptote (describing the maximum amount of agricultural land) to match the required protected area. The asymptote in the land supply function depicts the upper bound of the available land to be used in agriculture. The closer land supply approaches the asymptote, the sharper increase in land prices is required to convert additional land in use. In the half-earth scenario, the availability of future land expansion is reduced significantly, which corresponds to moving the asymptote to the left (in figure 1 the blue curve becomes red). As seen in the Figure 6, this will result in much sharper increase in land prices to higher land scarcity. This directly impacts the cost of all primary agriculture production and dependent sectors. Intensification is increased as investing more capital, labour and fertilizer can increase yields to reduce the land use pressure. Regions with higher possibility of expanding agricultural land (i.e. higher land availability) will be more impacted. An overview of the size of the land reduction shocks is reported in figure 7 below.

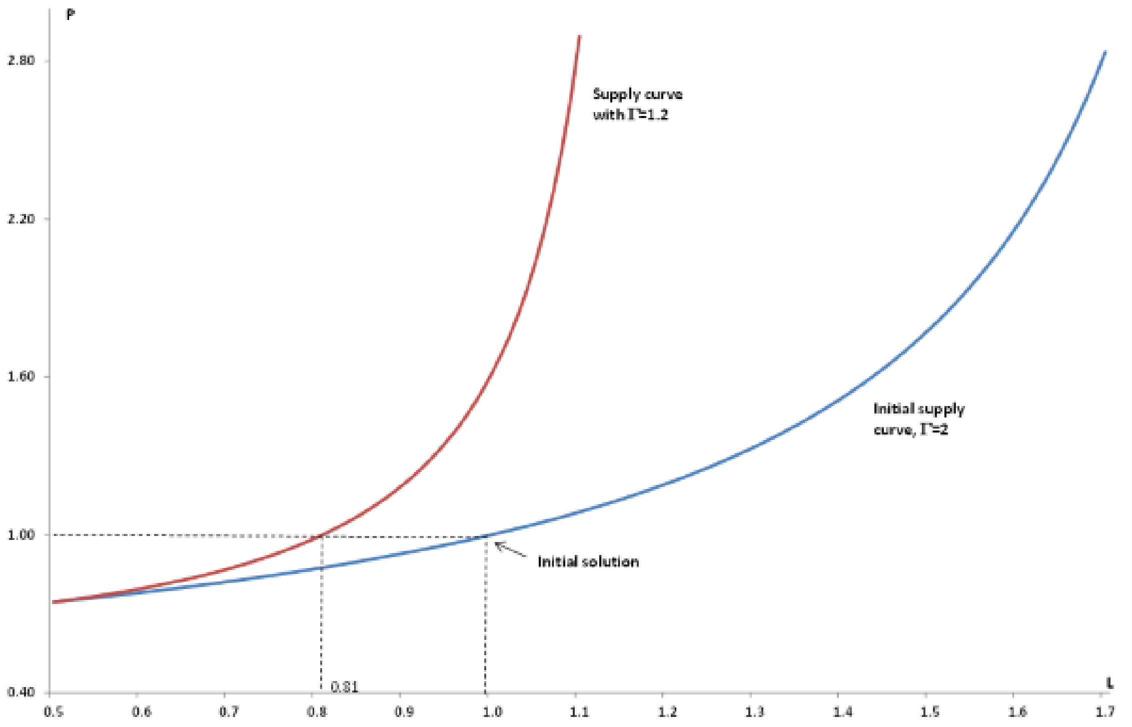


Figure 6. Land supply curve in the MAGNET model and implementation of the half earth scenario. The blue curve represents the land supply curve in the baseline scenario. The red curve represents the land supply curve in the half earth scenario.

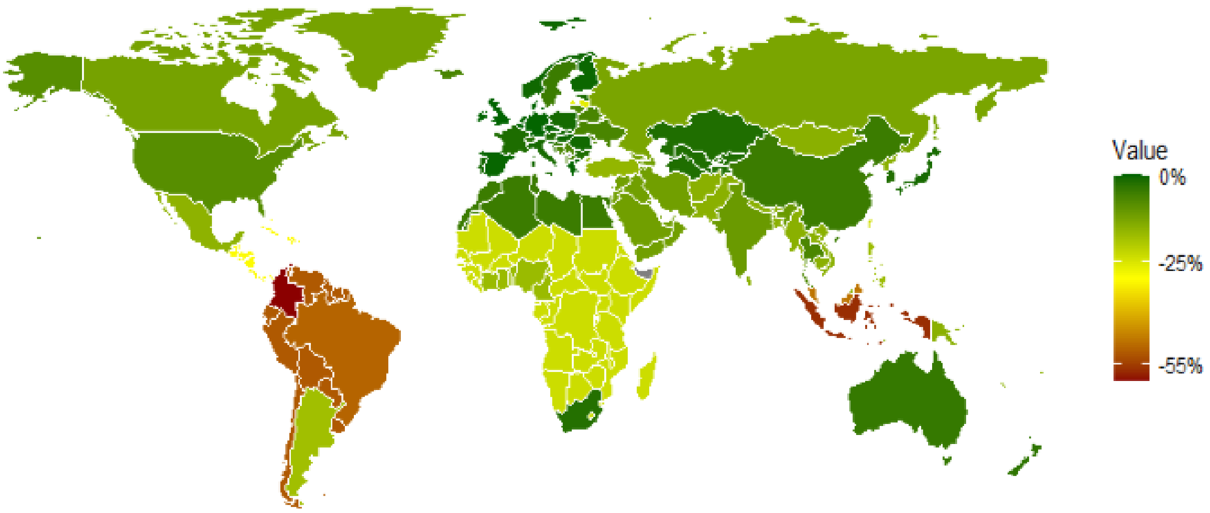


Figure 7. Magnitude of region-specific shocks in the half earth scenario. The magnitude of the reported shocks refers to the reduction (%) of land available for agriculture across different regions.

The "Half Earth" scenario leads to significant changes in land use and fertilizer application, as agricultural systems adapt to reduced land availability. On average, countries relying on extensive agriculture (land-intensive) are more negatively affected than countries relying on intensive agricultural systems (input-intensive), as the latter are relatively less exposed to the negative impacts associated with the reduction of land available for agricultural production. An overview of how the Half Earth scenario ripples through the whole economic system is illustrated in figure 8 below.

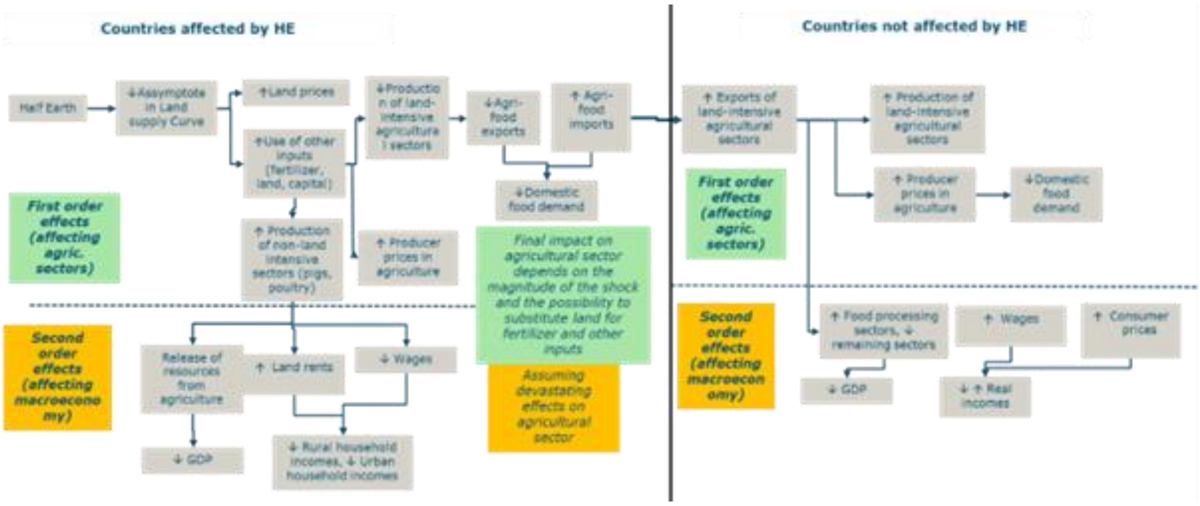


Figure 8. Flow-through effects in the Half Earth scenario compared to the SSP2 baseline scenario in 2050.

5. Frequently asked questions

5.1. What are the key assumptions in CGE models?

CGE models rely on several foundational assumptions to simulate economic behavior and market dynamics. One key assumption is that all markets clear, meaning supply equals demand for goods, services, and factors like labor and capital. This equilibrium assumption simplifies analysis but may not capture real-world phenomena like unemployment or excess supply. Another critical assumption is perfect competition, where producers and consumers act as price takers, and no single agent has market power. Firms maximize profits, and households maximize utility. This simplifies the modeling but doesn't account for monopolies, oligopolies, or pricing strategies. Additionally, CGE models assume rational behavior where economic agents (households, firms, and governments) are assumed to make decisions logically and with complete information, aiming to maximize their respective objectives. This assumption may not always reflect actual decision-making influenced by behavioral biases or imperfect information. Constant returns to scale are often assumed, meaning output increases proportionally with inputs, which overlooks sector-specific economies of scale. Prices in CGE models are also assumed to adjust flexibly and instantaneously to ensure markets clear, ignoring real-world price stickiness. Finally, the Armington assumption differentiates goods by country of origin, ensuring that imported and domestically produced goods are imperfect substitutes, which better reflects trade realities.

5.2. How are sectors connected in a CGE model?

In a global CGE dynamic model, sectors are interconnected through several economic relationships. Inter-industry linkages are captured using input-output tables, which describe how sectors depend on each other for intermediate goods and services. Each sector has a production function that specifies how various inputs like labor, capital, and raw materials are combined to produce output, and these inputs are either sourced domestically or through imports. Sectors are also linked through consumption and demand, where households, firms, and governments demand goods produced by other sectors. This demand influences production and consumption flows between sectors. International trade further connects sectors globally, as goods and services produced in one country can be exported or imported, affecting production and consumption patterns across regions. Factor markets, such as labor and capital, also connect sectors by allowing resources to move between industries based on returns. Prices play a central role in sector connections, as changes in input costs or output prices affect production and consumption decisions. Lastly, ongoing policy measures, such as taxes or tariffs across countries, create feedback effects that propagate through sectors, influencing production, prices, and trade flows. These interconnections enable CGE models to simulate the economy-wide impacts of various policies or shocks.

5.3. How Are International Trade and Capital Flows Modelled?

CGE models incorporate trade dynamics using the Armington assumption, where goods are differentiated by their origin (e.g., U.S. wheat vs. Canadian wheat), allowing for more realistic substitution between domestic and imported goods. This prevents extreme substitution between domestic and imported goods when relative prices change. Moreover, it enables the analysis of trade flows and the effects of policies like tariffs and subsidies. Trade policies, including tariffs and export incentives, are explicitly modelled to capture their economic impacts. For capital flows, static CGE models often assume capital remains fixed within countries, while dynamic models such as MAGNET, allow capital to move between countries based on returns. These flows are crucial for understanding how global financial markets interact with trade. Global trade databases, such as the GTAP database, provide the bilateral trade, tariff, and production data required to model these interactions.

5.4. What are the limitations of CGE models?

CGE models, while powerful, have several limitations. They rely on simplifying assumptions like perfect competition and rational behaviour, which may not fully capture real-world complexities like monopolies or behavioural biases. Results are highly sensitive to the quality of input data, such as Social Accounting Matrices (SAMs) and elasticity parameters. The calibration process, often based on limited empirical evidence, can introduce biases. Many CGE models are static and only capture short-term effects, missing longer-term dynamics such as investment and technological change. Moreover, CGE models struggle to quantify non-market factors like cultural or political influences. For this, outputs, typically defined as percentage changes relative to a baseline, require a careful interpretation for being contextualized into real-world terms. Finally, while useful for scenario analysis, these models are not predictive and may not account for unforeseen economic shocks or political events.

5.5. What type of data do CGE models require?

CGE models rely on extensive and detailed datasets to simulate economic systems and analyze policy impacts. A key component is the Social Accounting Matrix (SAM), which captures economic transactions among households, firms, governments, and the external sector, providing a comprehensive view of income flows and resource allocation. Input-Output (I-O) tables are also essential, illustrating how industries are interconnected, with outputs from one serving as inputs for another. These tables help track the cascading effects of policy changes across supply chains. Behavioral parameters, known as elasticities, quantify how economic agents respond to changes, such as shifts in prices or income. These are critical for modeling substitution effects and behavioral adjustments. Global CGE models additionally require detailed trade data, including bilateral trade flows, tariff schedules, and transportation costs, to accurately represent international trade dynamics. Together, these data inputs allow the model to be calibrated to replicate the economy's baseline equilibrium, enabling "what-if" scenario analyses. The quality of the data directly influences the reliability of the model's predictions.

5.6. How reliable are CGE Model Results?

CGE models are primarily tools for scenario analysis rather than precise predictions. Their reliability hinges on several key factors. First, the quality of the underlying data and the accuracy of the model's calibration play a crucial role. The model must be carefully calibrated to reflect the actual structure and behavior of the economy it seeks to represent, using data such as Social Accounting Matrices, Input-Output tables, and trade flows. Second, the plausibility of the model's assumptions significantly affects its reliability. For instance, the choice of elasticity parameters, which determine how economic agents respond to changes in prices or incomes, must be grounded in empirical evidence. If these assumptions are unrealistic or poorly estimated, the model's results may be misleading. Finally, robust sensitivity analysis is essential to gauge the reliability of the results. By testing how changes in key parameters or assumptions influence outcomes, researchers can identify the degree of uncertainty in the model's predictions and assess the stability of its conclusions. While CGE models provide valuable insights into potential economic impacts and policy trade-offs, their results should be interpreted with caution and used in conjunction with other analytical tools. They are best viewed as frameworks for exploring "what-if" scenarios rather than definitive forecasts.

5.7. How reliable are CGE Model Databases?

Global databases like GTAP and WIOD are widely used in CGE modeling and are considered highly reliable for consistent trade, production, and consumption data across regions. However, these databases often lag in time, meaning the data may not reflect the most recent economic conditions. National databases, while more current, may vary in quality and coverage, with data gaps being a common issue in developing countries. Elasticity parameters, often derived from empirical studies, may not always align with the specific context of an analysis. Databases are periodically updated and cross-validated against other sources to maintain accuracy, but gaps and inaccuracies, particularly in developing regions, remain a challenge.

5.8. How do CGE models differ from partial equilibrium models?

CGE models and partial equilibrium models differ primarily in their scope and complexity. CGE models analyze the entire economy, capturing the intricate interactions among sectors, households, firms, and governments. This makes them particularly suited for evaluating policies with far-reaching, economy-wide implications, such as trade agreements, carbon taxes, or significant fiscal changes. By considering the interdependencies across sectors and markets, CGE models can assess how changes in one part of the economy, such as energy prices, ripple through to affect manufacturing costs, household consumption, or even trade flows.

In contrast, partial equilibrium models focus on a single market or sector while holding other markets constant. This narrow focus allows for simpler construction and interpretation, making these models useful for analyzing specific policies or interventions within a particular sector, such as the effects of a subsidy on agricultural production or the impact of a tax on the energy sector. However, this simplicity comes at a cost. Partial equilibrium models fail to capture cross-sectoral feedback, which can lead to an incomplete understanding of the broader economic effects. For example, they would miss how changes in energy prices might influence other industries or household spending patterns.

While CGE models are more complex and data-intensive, they provide a holistic view of economic dynamics. This makes them essential tools for analyzing policies or shocks that have spillover effects across multiple sectors or regions, offering insights into the broader implications that partial equilibrium models cannot address.

5.9. Can CGE models handle market imperfections or externalities?

Yes, advanced CGE models can incorporate market imperfections and externalities, making them more realistic in representing real-world economic dynamics. For example, these models can account for imperfect competition, where firms exercise market power, such as in monopolistic or oligopolistic markets. This allows the model to capture situations where companies can influence prices or output, deviating from perfect competition assumptions.

In addition to market power, CGE models can also include externalities, which are costs or benefits that affect third parties but are not reflected in market prices. Common examples of externalities included in CGE models are pollution, congestion, and innovation spillovers. By incorporating these factors, the models can more accurately reflect the social costs and benefits of economic activities, providing insights into policy measures aimed at mitigating negative externalities or encouraging positive ones. Moreover, CGE models can be extended to account for various policy distortions, such as subsidies, taxes, or trade barriers. These distortions can significantly affect market outcomes, and including them in the model helps simulate the effects of real-world policies, including trade restrictions, environmental taxes, or subsidies designed to promote certain industries. While these extensions increase the realism of CGE models, they also add to their complexity. Incorporating market imperfections and externalities requires more detailed data and assumptions, which can make the models more challenging to build and interpret. However, the added complexity enhances the model's ability to simulate more nuanced economic environments and provide deeper insights into the impacts of policy interventions.

6. Connecting MAGNET to NiGEM

The regional setup of the MAGNET model employed in BiROFin is compatible with the NiGEM model, and an earlier study of the Dutch National Bank[1] employed this connection to translate MAGNET results into NiGEM shocks. A key difference is the MAGNET scenarios for the DNB were comparative static, set in 2019 without any time dimension, whereas the time dimension was introduced in the NiGEM model. For full details, see the DNB report. Repoterd below some relevant exports and the mapping of MAGNET commodities. In this case, the related variable in MAGNET is the Consumer Prices (XPRC_idx) reported as an index.

Useful excerpts from the DNB study:

"To get the full macro-financial scenario that we need in order to estimate losses for financial institutions, we introduce price shocks coming from MAGNET into NiGEM. We map commodity groups between the two models on a best-effort basis (Appendix 1). For the mapped commodities, we impose the MAGNET shock in NiGEM as an exogenous shock that remains constant over time. We then simulate the macroeconomic response in NiGEM"

"Connecting nature-to-economy to pure economic models, which is necessary for a macro-financial scenario that can feed into scenarios analyses, is challenging. Tackling these challenges DNB Exploring scenarios with transition and physical shocks inevitably involves very strong simplifying approximations. For this study, we needed to map economic estimates produced by the MAGNET model into the NiGEM macroeconomic model in order to generate the macro-financial scenario needed for estimating the losses of financial institutions. The initial shock in MAGNET generates a set of effects on both price and GDP. The next step in NiGEM uses the price effects for 5 main commodity categories from

[1] https://www.dnb.nl/en/publications/research-publications/occasional-study/nr-2-2023-the-economic-and-financial-stability-repercussions-of-nature-degradation-for-the-netherlands-exploring-scenarios-with-transition-shocks/

MAGNET as a set of exogenous shocks in NiGEM. Subsequent macroeconomic effects are computed solely in NiGEM. While this approach is necessary for generating a fully internally consistent macroeconomic scenario in NiGEM, it does mean we chose to ignore the detailed macroeconomic information produced by MAGNET, such as sectoral movements in value added. This might not always be a fair reflection of reality.”

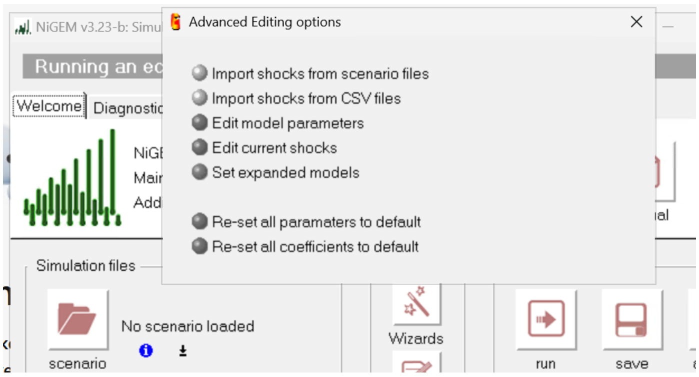
Input from Sebastien Gallet (DNB)

We took a variation of prices from MAGNET (e.g. -5%), which corresponds to one commodity in Nigem, with the following equivalency table (Table 1).

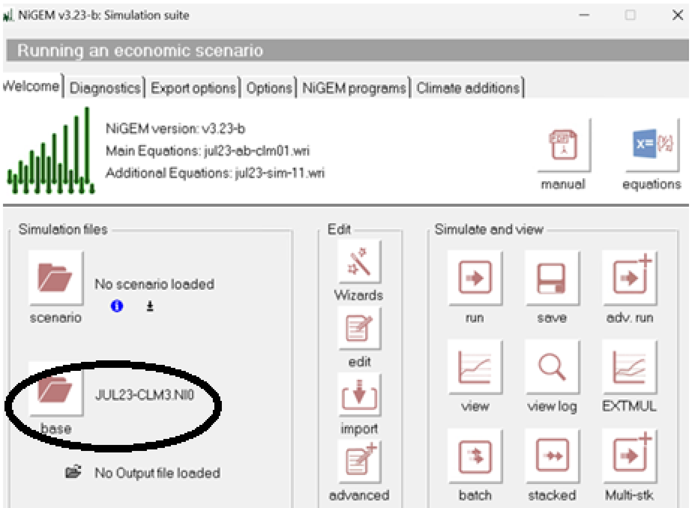
Table 1. Equivalency for commodities.

MAGNET	Nigem		
description	description	suffix	Type
Agricultural products	Agricultural raw material prices, index	PANF	World index
Beverages and tobacco products	Global beverage prices, index	PFLD	World index
Oil	Oil price, index	PO	Country
Gas	Gas price, index	PG	Country
Coal & consumable fuels	Coal price, index	PF	Country
Processed/packaged food and meats	Global food prices, index	PFDV	Country
Industrials	Metal prices	PMM	World index

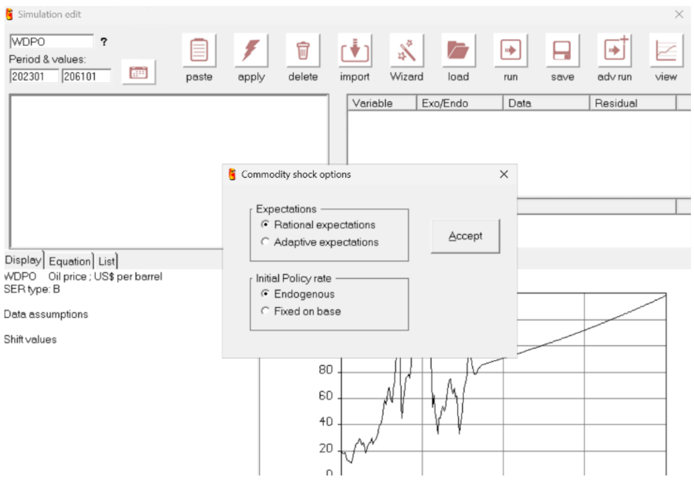
In Nigem, PO, PG, PF, and PFDV are defined at the country level. This means that it is essential to define these variables for each individual country. To streamline this process, it’s necessary to automate the definition of shocks in Nigem using a .csv file listing (an option provided by the software, though it’s not the easiest to use).



In Nigem, the first phase consists in running a benchmark scenario without shock. There is always such a scenario specific to every version of Nigem.



We obtain then a time series of commodities prices evolution. The shock from MAGNET is applied as a percentage and as a parallel shock across the entire series. The concept is that the potential loss information is immediately and permanently integrated by the market, resulting in a parallel shift of the price. It is then necessary to define the type of shock according to the retained modelling. Endogenise or Exogenise and Rational or Adaptative. We used Exogenise and rational but we analyse the sensitivity to other possibilities.



Finally, each shock is a parallel shift of commodity prices and for all countries (more 100 variables).