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InnWater Article

#9 Computable General Equilibrium Model and WEFE Nexus

INN WATER

Promoting social innovation to renew multi-level and cross sector water governance

UNIVERSITÉ DE ROUEN NORMANDIE

Context

A **computable general equilibrium (CGE)** model is a **macroeconomic simulation** and analysis tool. The CGE model represents, in mathematical functions, the economic mechanisms of exchanging monetary values between economic activities, **factors**, **agents** and **markets** (including prices). Thus, the CGE model can simulate a whole economic system at a macroeconomic scale. CGE models are used to analyse economic scenarios, such as economic shocks or policies (e.g., water scarcity or pricing policies). CGE model simulation results are usually expressed in relative changes compared to the **reference scenario**. Thus, the CGE model simulation can inform how the economic system changes because of changes in settings compared to the situation if the economic settings stay unchanged. Thus, CGE models are not forecasting instruments; they only analyse how the economy changes if certain events occur. With this, CGE models help researchers analyse the impacts of events and understand the direct and indirect **economic mechanisms** that can appear during such an event. CGE models are calibrated to the data of a **Social Accounting Matrix (SAM)**, which represents a snapshot of a country or region in a given year. CGE models can represent different temporal (static or dynamic) or regional resolutions (single-country or multi-country).

Definition

Computable General Equilibrium (CGE) models are macroeconomic models that represent the economic equilibrium between all economic activities, agents, and markets in a circular monetary flow. The "general" equilibrium contrasts the "partial" equilibrium in **Partial Equilibrium (PE)** models, which represent only a part of the economic system (e.g., specific sectors or agents). "Computable" indicates that the model is based on algebraic functions and can be numerically solved. A CGE model is based on macroeconomic data and rigorous macro and microeconomic theory.

A **macroeconomic analysis** considers the economy as aggregated units, i.e., as representative agents. It does not consider the economic units as individuals (e.g., individual households or persons). In contrast to "macroeconomic" analysis, a **"microeconomic"** analysis considers

economic individuals and their economic behaviour and situation (e.g., individual households or persons).

In a CGE model, **activities** (also called sectors or industries) represent the production of commodities and services. Activities require production factors and **intermediate commodities** (intermediate consumption) to produce.

Factors in a CGE model refer to production factors, which are **productive resources** used to produce commodities and services. Production factors include labour (e.g., employees' working time), capital (e.g., machines, livestock), and **natural resources** (e.g., land and **water**).

In a CGE model, the **agents** (or institutions) are economic actors in form of representative agents. Typical agents in a CGE model are **households**, the **government**, and the **rest of the world**. Households own the production factors (e.g., labour) and sell them to the activities. Thus, households receive factor income and transfers (e.g., social aid from the governement) and spend it to buy commodities, to pay transfers (e.g., taxes) or to do savings.

Commodities comprise both goods and services and are produced by activities. They either come from **domestic** or from **international markets**. They are bought by households for consumption, by activities as intermediate commodities (i.e., input for production), and by importing countries and used as **investement goods**.

Markets link the activities' production with the agents' demand by computing a price for the commodities for which producers are willing to sell and households are willing to buy, i.e., the **equilibrium price**. In a CGE model, the markets interlink all activities, commodities, and agents by equilibrium **prices**. In simulations, the equilibrium prices change, and these changes spill over to the whole economic model system.

A **Social Accounting Matrix (SAM)** is a macroeconomic framework that consistently represents the situation of an economy for a specific year. This year is often used as the **reference or base year** to which the changes of a CGE model are compared to. The SAM represents the exchange of **monetary values** between production activities, commodity markets, and economic agents. SAMs exist typically for national economies (at the national level). The cells that represent economic activities, commodities, and agents are called **accounts**.

The results **in a CGE model** are macroeconomic **indicators**, respectively their changes compared to the reference or base year. Typical results of a CGE model indicating the change in an economy are the change in the **gross domestic product**, the change in **sector production**, commodity **prices** household (private) **consumption**, **government's income** and **trade flows**.

WEFE-Nexus in CGE models

While CGE models represent the economic system as a circular nexus, where **monetary values** are exchanged and transformed, the WEFE-Nexus is a resource nexus of **biophysical nature**. Using a CGE model for WEFE-nexus analysis requires linking the monetary economic nexus with the biophysical resource nexus. SAM usually include some WEFE-nexus pillars as accounts. Thus, CGE models based on such a SAM simulated the WEFE-nexus pillar as activities, factors or commodities. Typical WEFE-nexus pillars in SAMs are the **agricultural and food processing activities and commodities** (for the "food" pillar) and the **energy activity and commodities (for the "energy" pillar)**. Within a CGE model, these activities are interlinked with other activities and commodities. Linking the CGE model with the WEFE-nexus pillars outside the SAM framework requires **including the biophysical information** of the resource nexus in the SAM. **Figure 1 presents the CGE model as the economic nexus** embedded in the

WEFE-resource nexus (with a grey background). The information of the WEFE-Resource Nexus is fed into the SAM and enters from there the CGE model. Within the CGE model, activities and agents exchange money via markets and transfers (blue arrows on white ground).

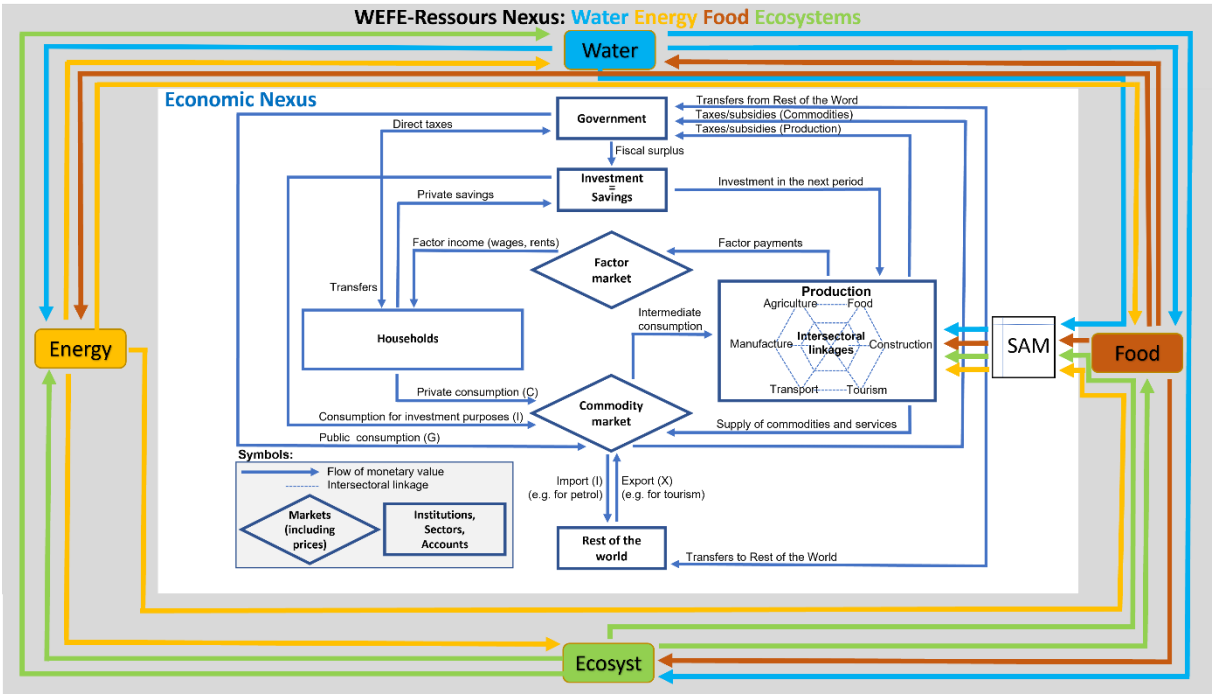

Figure 1: WEFE nexus and CGE model. Source: adapted from Henseler et al. (2022) Economic impacts of COVID-19 on the tourism sector in Tanzania. Annals of Tourism Research Empirical Insights 3. 100042

Link with InnWater

The WEFE nexus pillar of primary interest is "water" (in **Figure 1**, the blue arrow on the grey background). For the CGE model, water enters the economic system as a production factor (e.g., **groundwater** or **surface water**). The production factor water enters production processes directly (e.g., as irrigation water in agriculture) or is processed before as **piped water** by the **water provider**. Piped water is supplied to other industries and households. The intersectoral linkages between water and the other WEFE nexus pillars are defined by water usage for consumption or production. Industries using raw water reduce natural water **resources** and **emit pollutants** into the water as an **Ecosystem** (the Ecosystem or Environment pillar). **Energy** is used to produce water and food. However, energy consumption creates emissions to the environment (CO_2 emissions) as linked to the Ecosystem pillar. Energy production also requires water, e.g., cooling water. The **production of food** (i.e., the Food pillar) requires water and, at the same time, contributes to the pollution of water as an ecosystem (e.g., by the application of fertiliser and pesticides). Last but not least, raw water is processed as **piped and consumed by households** as drinking water. In InnWater, a CGE model is developed to analyse the interactions between water use, energy production, and economic activities in **Reunion Island**.

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