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ANALYSIS OF THE COMPUTABLE GENERAL EQUILIBRIUM METHOD USE. SOFT-LINKAGE WITH TIMES MODEL.

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ANALYSIS OF THE COMPUTABLE GENERAL EQUILIBRIUM METHOD USE. SOFT-LINKAGE WITH TIMES MODEL., 2020, 39 pages.

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INTRODUCTION

The task of LU researchers: to develop such a computable general equilibrium model (CGE) that allows to assess the economic effects of energy policy on the economy of Latvia in cooperation with TIMES model experts.

During the reporting period the activities of LU researchers included:

1) analysis of the current situation and studies of scientific literature on the aims, problems and applications of the CGE model development and the software used for evaluation;
2) studies of scientific literature on the possibilities of linking TIMES type and CGE type models; examination of the experience of several countries (Sweden, Finland, Portugal, Norway);
3) identification, compilation and analysis of the level of detail of available statistical information, creation of data files (xlsx) and model database (creation of har files);
4) acquisition of GEMPACK software;

One representative of the researchers of the University of Latvia attended the intensive applied assessment course for general equilibrium models with the GEMPACK software: "Practical GE Modeling Course". The courses took place in Vienna, Austria on September 9-13, 2019 at the Austrian Center for Economic Research (WIFO), lecturers were from Australia - Victoria University's professors working at CoPS (Center of Policy Studies). Aim of the course: to provide a theoretical basis for modelling the general equilibrium in an open economy as well as a practical adaptation of the ORANI-G type model for the assessment of specific policy effects in a specific economy. At the end of the course skills in working with GEMPACK were obtained along with knowledge of what, in what way and why should be changed in databases and programmed in command files to perform simulations for evaluating short- and long-term effects.

A small MINIMAL model (its adaptation to Latvian data) was used in the team at the beginning for acquiring GEMPACK and ORANI-G operations, later a large model with WIOD input-output division in 35 sectors was created (latest data for 2014), as a result, CSB data (latest data for 2015) were chosen, dividing them into 20 sectors only. (The list of industries is given in Appendix 1). On the one hand, the reduction in levels of detail could indicate a decrease in the quality and applicability of the CGE model, but on the other hand, it is more likely model's optimization, since some of the sectors given by WIOD are not developed or are underdeveloped in Latvia, as well as the transparency of the link between the two models was considered.

5) identification of model assumptions;

6) development of the model’s structure and drafting the model’s scoreboard file; working out and calibration of the model, as well as analysis and evaluation of the provisional results of the model and working on the improvement of the model.

At the beginning of the deliverable a description of the general equilibrium calculation models is given in the form of scientific literature’s review. The review is followed by a brief description of Latvia's computable general equilibrium model, its database, assumptions and opportunities of improvement. Then, the possibilities of creating the most effective connection between CGE and TIMES models are considered as well as an illustrative example of one iteration is given. Finally, conclusions on the progress of the work so far and proposals for improving the link between the CGE model and the TIMES model are provided.

1. COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR LATVIA

1.1. Literature Review

Model History and Types

The developed Computable General Equilibrium (CGE) model is based on the theoretical approach to the existence of general economic equilibrium. The model was initiated in Australia in the late 1970s and then evolved over several decades.[1] At present this approach is widely used in academia for practical economic policy analysis and forecasting as well as for economists in ministries, other public institutions and private bodies in many countries around the world.[2] General equilibrium models have been developed for Australia, the United States, Japan, Ireland, Denmark, Brazil, the Republic of South Africa, China, the Philippines, Fiji, Thailand, Vietnam, Korea, Malaysia, Pakistan, Indonesia, Kazakhstan and adapted for use in other countries worldwide (see Fig. 1).

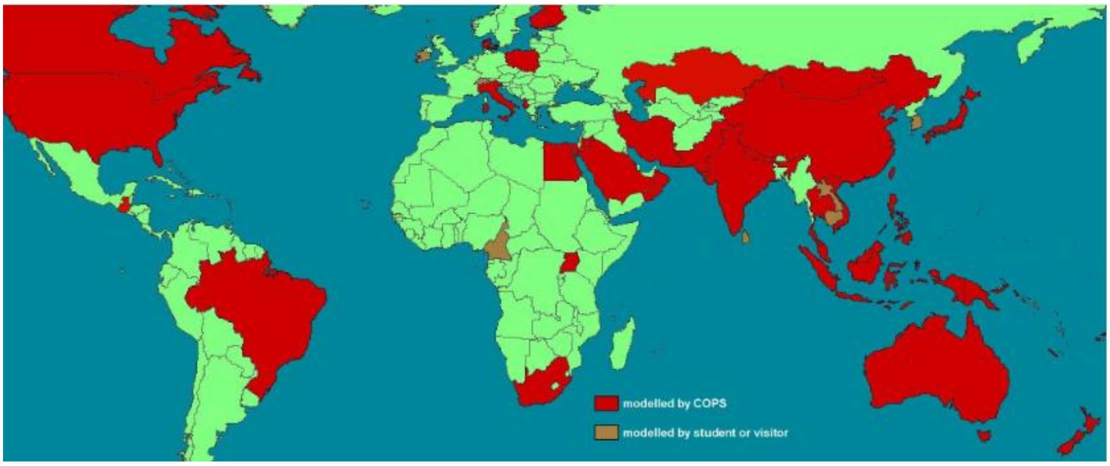


Fig.1: Geographical location of users of CGE models developed in Australia

Source: https://www.copsmodels.com/

Analysts use different versions of the general equilibrium model according to the specific goals and objectives of economic analysis and forecasting: single country model without regionalization (ORANI, MONASH), regional models (TERM and VURM), and finally global general equilibrium models (GTAP).

[1] Pearson, K.R., Parmenter, B.R., Powell, A.A., Wilcoxen, P.J., Dixon, P.B., Notes and Problems in Applied General Equilibrium Economics, Vol.32., 1992

[2] Parmenter and Meagher, 1985; Powell and Lawson, 1989, Powell, 1991; Vincent, 1989.

The beginnings of economic equilibrium can be traced back to the 18th century, when the general principles of market equilibrium were described in 1776 by Adam Smith and his principle of the "invisible hand". A century later, mathematical calculations of market equilibrium principles were performed by French mathematician Antoine Augustin Cournot and French mathematician-economist Marie-Esprit-Léon Walras.

It is Walras, whose contribution is considered as an essential basis for further research on market equilibrium and who is held to be the founder of the general equilibrium calculation model (Walras & Williams, 1954). Walras (1954) developed a general model of competitive market exchange, but provided only an informal argument that this model has market equilibrium. Wald provided evidence for a simplified version of the Walras model based on further studies by Debreu (1952), Arrow & Debreu (1954), Gale (1955), Nikaido (1956), McKenzie (1959), Negishi (1960) and other researchers. Walras realized that his arguments had to be based on a theory of price adjustment that would ensure balance and stability. He believed that the main force leading to equilibrium was the competition he saw in the price adjustment of regular economic actors (Gintis & Mandel, 2013).

Substantial Arrow-Debreu model, elaborated in 1954 by Kenneth Arrow and Gérard Debreu, is certainly worth mentioning here. This model assumes, under certain assumptions (convex preferences, full competition, and independent demand), that at certain prices for each commodity group in the economy, aggregate supply will be equal to aggregate demand. This model is one of the main ones used in other microeconomic models and computable general equilibrium (CGE) models (Arrow & Debreu, 1954). McKenzie is also mentioned among researchers who made significant contributions to the development of the CGE model at this time (L. McKenzie, 1954; L. W. McKenzie, 1959).

The CGE model was developed and adapted to various studies over time. For example, in 1972 Shoven & Whalley refined the Arova-Debro model and supplemented it with taxes and tariffs for estimating the impact of fiscal policy on the economy. Although the original Arova-Debro model included taxes in a simplified version, Shoven & Whalley made it possible to analyze all types of taxes in more complex economic situations (Shoven & Whalley, 1972).

The Computable General Equilibrium (CGE) model has a long history and many researchers have contributed to it. For example, the innovative research of W. Leontief, which introduced the cost and output system, and the works by L. Johansen, who analyzed Norway's first CGE model, which included 22 industries, are sufficient. (Beņkovskis, Goluzin, & Tkačevs, 2016).

One of the most important achievements in the applied economy since the 1970s has been transforming the well-known Walras general equilibrium structure from an abstract representation of the economy to real economies with making policy assessments, indicating production and demand functions and incorporating real information (Levin, 2006).

Since then, CGE modeling has significantly improved. The growing popularity of CGE models was mainly due to their ability to quantify the different effects of economic policies and shocks on different sectors, regions, and social and economic groups. These types of models are well-suited to discovering answers to monetary policy questions that require going beyond the general macroeconomic situation. For example, how does a productivity shock in one sector affect output in other sectors? How do changes in the VAT rate of a product affect consumers? In what way an external shock affect employment in economic sectors? Answers to such questions cannot be found (at least in sufficient detail) using most traditional, semi-structural macroeconomic models or dynamic stochastic general equilibrium (DSGE) models, although a number of recently developed multidisciplinary DSGE models are available (M. Bukowski and P. Kowal, M. Antosiewicz and P. Kowals). With the CGE model (compared to the DSGE model) it is relatively easy and efficient to find answers to these questions (Beņkovskis et al., 2016)

The application of the CGE model in practice is versatile and in the scientific literature and practice it is used to analyze:

- tax reforms (Álvarez-Martínez et al., 2019; Bhattarai, Nguyen, & Nguyen, 2018; Freebairn, 2018; Llambi, Laens, & Perera, 2016)
- trade liberalization (Bchir, Decreux, Guérin, & Jean, 2002; Europe Economics, 2016)
- economic integration (Pelipas, Tochitskaya, & Vinokurov, 2014)
- world price changes (He, Zhang, Yang, Wang, & Wang, 2010; Li, 2010; Siddig & Grethe, 2014)
- sustainable economic growth (Böhringer & Löschel, 2004; Christoph, 2004)
- changes in fiscal policy (Benkovskis et al., 2016; Mabugu, Robichaud, Maisonnave, & Chitiga, 2013; Sophat, 2015)
- energy and environmental policy (Barbe, 2013; Weitzel, Ghosh, Peterson, & Pradhan, 2015)

The CGE models have been the standard tool for large-scale impact assessments since the late 1980s. They cover a wide range of topics, such as free trade agreements, government or institutional policies, economic scenarios (such as new infrastructure investments) and events (such as drought or oil spills). The CGE model is a quantitative method that simulates key economic interactions. It uses data on the structure of the economy to assess the effects of a shock (e.g. on GDP growth, employment, inflation, trade flows, etc.). Despite their relevance in modeling policy consequences, the CGE models are often perceived with suspicion as a 'black box', the results of which cannot be traced due to their structural complexity. The CGE models differ in their theoretical framework and the underlying assumptions.

The distinctions between the models reflect the differences in the theory underlying the behavioral equations, the extent to which the links in economics are explained and the data used to perform the analysis. In general, CGE models differences arise from (Europe Economics, 2016):

- geographical scope (i.e. regional or national or international) - CGE models can cover several regions within a country (i.e. several regions) or only one region (i.e. at national level). The regional CGE model is based on regional economic theory, as the interaction of regions varies from the interaction between countries. For example, the impact of national incentives on regional quality of life and interregional migration is not reflected in national models, but can be modeled in a regional model. Regional CGE models also reflect the region's impact on national trade patterns. In contrast, national or international models assume that regional activities do not affect the rules and patterns of international trade.
- time structure (i.e., static or dynamic) - a static CGE model is solved for one period, but a dynamic CGE model includes several periods. The dynamic group has another sub-category division between time-dynamic models and recursive dynamic models. In the first case, consumers and businesses face the problem of maximizing efficiency and profits; in the second case, the model solves a sequence of static equilibrium in which the behavior is indirectly based on past adaptive expectations rather than future-oriented rational expectations.
- underlying market structure (i.e. complete against imperfect competition) - CGE models may include alternative market structures. Incomplete competition can be achieved by introducing a price mark-ups. An essential feature of the presumption of unfair competition is that price mark-ups are reduced by increased competition linked to policy shocks, thus leading to additional welfare gains. On the other hand, an essential feature of the presumption of full competition in tariff simulations is that tariff reductions are fully passed on to consumers.

- inclusion of FDI - An increasingly important feature of the CGE model is the inclusion of foreign direct investment (FDI). This is essential to model the impact of investment in modern trade agreements and to assess the impact of liberalization in the services sector.
- inclusion of heterogeneous enterprise characteristics - if the standard CGE models have a representative enterprise in a particular sector, then in the case of heterogeneous enterprises the model indicates that there are different enterprises in the sector with different characteristics such as enterprise size, productivity and other characteristics. In addition, the theory states that companies face fixed costs for entering export markets. Several CGE models have been developed recently, introducing elements of corporate heterogeneity. However, such attempts are still at an early stage of development.

The CGE models begin with defining a pre-policy framework in which simulations are performed with the aim to determine post-policy effects. The base is constructed using base year data (i.e. before policy) to identify exogenous variables in the model (setting model equations and behavioral parameters for the data). This means that the model is designed to model the impact of a shock on the current economic structure, which is considered to be a stable or balanced position.

Implementation of CGE Model in the Evaluation of Energy Policy Effects

There are a lot of examples in the literature where the computable general equilibrium model is used to model the effects of energy policy measures. In Norway it is a common practice to assess policy-making objectives through the development and application of disaggregated multi-sectoral general equilibrium models. The tradition relies on the work of Leif Johansen (1960, 1974). Since the early 1970s, the work has been carried out mainly by the Research Division of Statistics Norway. Over time, energy and emissions modules have been integrated into the basic economic model, thus ensuring a consistent analysis of economic, energy and environmental issues based on a single comprehensive modeling system. The Norwegian government implements widely the extended modeling tool in preparing economic development, energy demand forecasts and emissions from the early 1980s to the present day.

Integrated economic-energy-environmental modeling in Norway also has more than 20 years of experience, its commencement can be found in Alfsen's (1996, 1997) research. The availability of energy and environmental statistics has made possible to develop computable multisectoral general equilibrium models (CGE models) with a rigorous description of energy supply and demand, as well as the link between economic activity, energy production and use and emissions. The impact on the environment is mostly closely linked to economic activity. Linking this impact through integrated economic-energy-environmental models is an important precondition for moving towards a sustainable economy and more accurate environmental forecasts. Over the last 15 years, models have evolved rapidly as they have had to adapt to a changing economic policy paradigm to address global climate change, with issues such as the development of optimal carbon tax or carbon allowance schemes (Bye, 2008).

Two opposing modeling approaches have emerged to address energy demand: a bottom-up engineering approach and a top-down macroeconomic approach (Wene 1996; Hourcade; Jaccard et al. 2006).

- The engineering approach tends to develop bottom-up models with a complete description of the technological aspects of the energy system and in what way it could evolve in the future. Energy demand is usually provided externally, and the model analyzes to what extent a particular energy demand should be met in a cost-optimal way.
- The economic approach seeks to build top-down models that characterize the whole economy and emphasize its potential to replace different factors of production in order to optimize social welfare. These models do not cover many technical aspects. The interaction of energy and other factors of production generating economic growth is embedded in production functions, and the potential for change in raw materials is described by the flexibility of substitution. Another important parameter for energy policy is autonomous energy efficiency improvement (Murphy, Rivers et al. 2007).

The two approaches are fundamentally different, they describe the economic system differently and can therefore lead to different proposals for policy makers. For production functions, top-down models will usually have a smooth replacement - slight price changes lead to minor changes in the combination of raw materials or output. Bottom-up engineering models will often react in a binary way: slight price changes may have no effect, or it may lead to significant changes in the combination of raw materials or output. Comparisons of both approaches and their value to policy makers are available (Algehed, Wirsenius et al. 2009).

The above mentioned modeling approaches are different but complementary. Combining bottom-up engineering models with top-down macroeconomic models is desirable for devising energy systems that are compatible with sustainable economic growth (Helgesen, 2013).

Bottom-up models fall into four main categories (Fleiter, Worrell et al. 2011, Herbst, Reitze et al. 2012):

• Optimization models

• Simulation models

• Accounting models

• Multi-agent models

Optimization models optimize the choice of technology alternatives in terms of total system cost aiming to find the lowest cost. Such models are also classified as partial equilibrium models because they balance supply and demand in the sectors covered. Simulation models form a very broad and heterogeneous group. Their modeling aspects are different from a pure optimization system. These may include econometric ratios. Large simulation models may involve partial optimization (for example, from a company perspective) and may consist of different modules covering more aspects. Accounting models are less dynamic and do not take energy prices into account. These models mainly concern external assumptions about technical development. Multi-agent models are broader than optimization models because they involve the simultaneous optimization of multiple agents.

The so-called "top-down" interconnected economic-energy-environmental models provide a consistent framework for both forecasting and policy analysis and evaluation of economic, energy and environmental policies, explicitly including the environment in the efficiency function. They have raised economists' awareness of environmental issues and broadened the views of environmental activists in the public debate claiming that environmental issues have an economic impact (Bye, 2008). “Top-down” modeļus kopumā var iedalīt četros galvenajos veidos (Herbst, Toro, Reitze, & Jochem, 2012):

- Input - Output models
- econometric models
- computable general equilibrium models
- dynamic system models

Input-output models track cash flows between different sectors of an economy and include both intermediate and final products from each sector. From these interrelationships, the monetary consequences of economic shocks or structural changes in an economy can be assessed. These models have no price dynamics and assume that prices are set externally - exogenously. Econometric models refer to time series analysis and evaluate the statistical relationships between economic variables over time to calculate projections from the resulting model. Copmputable General Equilibrium models are based on microeconomic theory and calculate how prices and activities change in all sectors in achieving overall equilibrium in economy. Like the first group, these models rely on input-output data from national accounts. Dynamic system models have predefined rules for the behavior of different model participants and enable complex nonlinear simulations to be performed on this basis.

1.2. Latvian CGE Model

Activities Performed During Research Development, their Characteristics

For the general equilibrium model's evaluation, GEMPACK software was purchased. Its developers created also the world-famous and widely applied ORANI type model. For Latvia's economy modeling the reserchers decided to adapt the ORANI-G (generic) model developed for one- country modeling. The project's following action will be the transition to the ORANI-RD model, which could facilitate the link with the TIMES model. The ORANI -RD model is a recursive dynamic (forecasting) model, such as a simplified version of the MONASH model, which would allow to supplement the general equilibrium calculation model with a time dimension.

The division into sectors or the level of detail of the model is determined by the requirement to link two different types of models - the general equilibrium model and the partial equilibrium model TIMES. The initially chosen division into 35 sectors was not successful due to problems with matching models with different structures, even in "soft-linking". As a result, it has been chosen to split the economy into 20 sectors.

There were already few adaptations of the ORANI type model in Latvia, but this time the challenge is not only the development of the general equilibrium model, but also its connection with the TIMES model, ensuring the achievement of the overall research goals. Considering this condition, Latvia's computable general equilibrium model is not designed in great detail, neither in terms of sectors, types of households, export recipient countries or labor force qualifications.

Model Assumptions

The classical CGE model is built on the assumption of the existence of a general equilibrium in the economy as a whole, covering the most important economic sectors and economic agents (enterprises, households, government and the rest of the world).

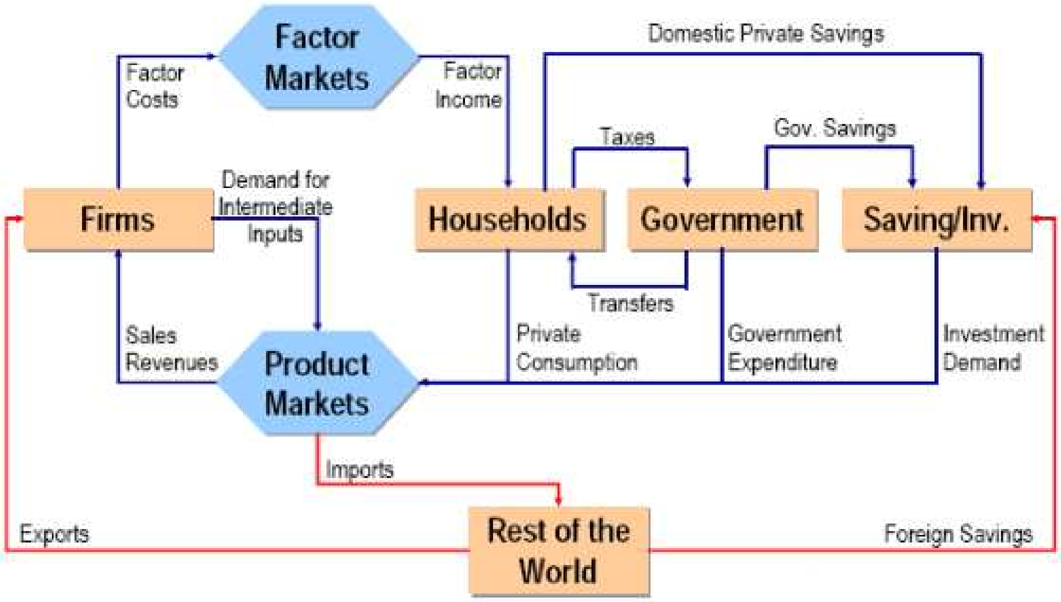


Fig. 2 Classical CGE model structure[3]

As shown in Figure 2, the CGE model includes economic agents (corporations, households, government and the rest of the world), flows of goods and services, and cash, maintaining and ensuring their commitment and, at the same time, balance in the economy as a whole.

The basic principles of the Latvia's CGE model are the same as in the ORANI-G model. It is a computable static model, its equations describe the situation in a period of time.

- it is assumed that the specific input-output table used in the model is the equilibrium point of the national economy;
- producers' demand is formed from the resources used in production (inputs, intermediate goods) and primary factors;
- producers' suply is manufactured goods;
- demand for the utilization of capital formation;
- households utilize the goods and services produced = household demand;
- export demand;
- government demand;
- the relationship between basic prices, producers' prices and purchasers' prices;
- market-clearing conditions for commodities and fundamentals;
- a series of relationships linking macroeconomic indicators and price indices.

[3] Pearson, K.R., Parmenter, B.R., Powell, A.A., Wilcoxen, P.J., Dixon, P.B., (1992) Notes and Problems in Applied General Equilibrium Economics, Vol.32.

The demand and supply equations of private sector agents are evaluated as a solution to the optimization problem (cost minimization and validity maximization). Thus, in the Latvia's CGE model, the behavioral equations of economic agents correspond to the neoclassical theory of microeconomics. The assumption is that agents are price takers operating in a competitive market.[4]

The CGE models, especially detailed, include many optimization tasks that can be solved simultaneously. The GEMPACK offers a solution to this problem by transforming nonlinear equations into percentage increments, thus linearizing them. The implementation of such an approach makes the model practical, as well as allows the researcher to change, if necessary, the assumptions about which variables are considered exogenous (they may be shocked) and which are endogenous. The choice of exogenous and endogenous variables is determined by whether a short-term or long-term shock is going to be assessed.

For reducing the approximation errors due to linearization, the Euler multi-step method is applied in the estimates.

Simplifications of the Real Situation Introduced in the Model

The model uses two types of classification according to the specifics of the input-output (INPUT-OUTPUT) tables. The breakdown applies to both industries (model with index IND) and goods (model with index COM). At present, it is also assumed that one industry produces one type of product. Consequently, the divisions into industries and products or goods (IND and COM) coincide. This assumption has been introduced to simplify the structure of the model, while recognizing that, in practice, companies in one industry often produce products in other industries to a greater or fewer extent. This difference is even more expressed in the service sector.

Each item can be either originating from a local manufacturer or imported. In Figure 3 of the CGE model, it is denoted by "Source" or S. The entire set of users in this model is denoted by USER.

One of the primary factors of production - labor force - in the Latvia's model is considered in the form summarized by sectors, that is, without a detailed division of labor force according to qualification, age, gender or other characteristics.

[4] Horridge, M. ORANI-G: A Generic Single-Country Computable General Equilibrium Model, 2014: https://www.copsmodels.com/ftp/gpextra/oranig06doc.pdf, 2.lpp.

Households are also used as an economic agent in a generalized way, without a breakdown by income level, household size or other characteristics.

The model uses the assumption that factors of production are interchangeable. Substitutability elasticities should be assessed and entered as exogenous information - separately.

The production process is divided into two stages for all sectors. Before starting the production process, each industry determines the total demand for the goods it produces and supplies to the market. It is assumed that all goods supplied by an industry have the same production structure. Therefore, the total demand is equal to the sum of the demand for the individual products produced by the industry. The total demand at company level can be considered to be defined. (Beņkovskis et al., 2016).

Both stages of the production process are described by a two-stage production function (Leontief production function), which is the basis for the optimization task - cost reduction. Other interaction processes of economic agents are also described in a similar way - solving optimization tasks.

Model Databases and Data Characteristics

The Latvian CGE model is based on the symmetric input-output matrices published by csb.gov.lv for 2015 (latest available data). Using the information collected in the Excel file, the data were regrouped according to the specified structure of the model, the number of sectors to be modeled and the possibility to match the scenario tools for linking to the TIMES model. By making sure that the data in the selected number of dimensions forms a symmetric matrix (are balanced), the information can be converted in a way that the GEMPACK software can accept. The data is then transferred to the GEMPACK software creating a Latvia.har file (Header Array File). The ViewHAR program is implemented for editing and modifying this file.

In the first version of the CGE, which was used to get aquainted with the software and explore its options, the created file had fixed dimensions ("small model": 7 industries, 7 products). By approbating it and personalizing it with TABLO software, it was achieved that the dimensions of the model can be changed more flexibly, without additional regrouping of data in an Excel file. This allows working more flexibly on linking CGE and TIMES models.

The database is regularly updated and expanded according to the improvement of the model.

The database structure of the Latvian CGE model corresponds to the general ORANI-G model. It reflects the basic structure of the model. When using GEMPACK for evaluation, the model descriptions use a unified notation system that corresponds to the TABLO syntax. The model input-output database structure is shown in Figure 3. All coefficients and variables relating to production are denoted by 1, investors by 2, households by 3, exports by 4, government by 5, stocks by 6.

The main source of the general equilibrium model is the *input-output* tables (IOT), obtained from the LR CSB database. At the same time, the IOTs publicly available in the World input-output database WIOD for Latvia and also for other European Union countries were processed with the aim to compare the structure of the economy and costs. The inportance of international comparison was determined by the fact that in order to use the CGE model in forecasting, it might be useful to consider the possibility of creating a "future equilibrium" model based on the assumption of Latvia's economic convergence with another EU country (e.g. Denmark). Detailed information about the IOTs themselves and how to work with them can be found in Timera, etc. (2015) and Timera et al. (2012) studies.

Initially, a larger number of industries and a wider range of goods were used in the Latvian CGE, but in the end the structure of the model was simplified (to be able to define the link with the TIMES model more clearly), and 20 industries and the same number of goods are distinguished (I = C). Households and labor are not futher categorized. Land is not used as a primary resource in the Latvian CGE model.

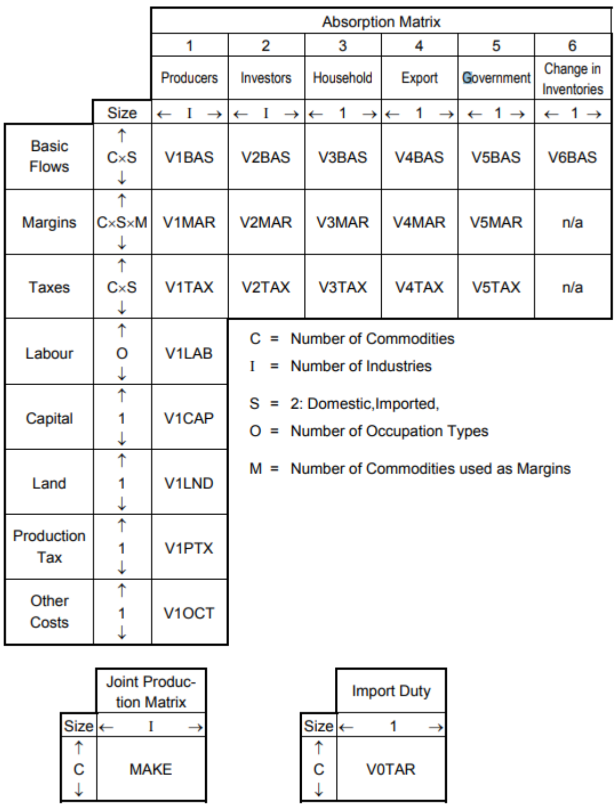


Fig.3. Structure and dimensions of the ORANI-G type general equilibrium model flow database [5]

In addition, the researchers continue the activities on testing the established database in relation to ensuring macroeconomic and sectoral balance during the reporting period.

Determination and Calibration of Parameter Values

Adaptation of the CGE database to the Latvian economy's modeling is not possible without establishing parameter matrices. Parameter estimates must be obtained outside the CGE model. The literature review (Bems and Giovanni (2016), Welsch (2008), Oleksevuk and Frosch (2016), Lundmark and Shahrammehr (2011), Nemeth et al. (2011) and Antimiani et al. (2015)) shows that much of the computable general equilibrium models use elasticity estimates derived from econometric methods to model time series or panel data, or simply adapt elasticity factors calculated elsewhere, such as from the GTAP database. A review of the estimates of substitutability elasticities published in the scientific literature leads to the conclusion that they are of a very wide range, which can be explained by the implementation of different methods and samples in the evaluation process. As Antoszewski (2019) emphasizes in his study, the reliability of the results of computable general equilibrium models depends directly on exogenous parameters such as substitutability flexibility - value assumptions. It is the elasticities of substitutability that determine how economic agents respond to price changes within the CGE. He emphasizes the heterogeneity of the estimates of elasticity coefficients used in CGE models, basing it on differences in methodologies. In his publication, Antoszewski (2019) obtained estimates for a large number of constant substitutability elasticity (CES) functions used for modeling different sectors, which are the basis of CGE. For the evaluation, he used panel data built on the WIOD database, as well as demonstrated the different levels of CES function elasticity estimation techniques that we plan to use to obtain our estimates for Latvian data.

Thus, in addition to the input data file of the Latvian computable general equilibrium model, a parameter matrix was created. It included assessments of substitutability elasticities and other parameters for characterizing the Latvian economy. The values of the parameters were determined using two methods - some of the parameters were estimated with the support of econometric models, some were borrowed from previous studies on Latvia (for example, the CGE model developed by the Bank of Latvia in 2016) and results published in other countries.

[5] Horridge, 2011, https://www.copsmodels.com/ftp/gpextra/oranig06doc.pdf: 9.lpp.

Since the simulation results of the CGE model depend on the values of exogenously set parameters in the model, the choice of these values is of great importance. Especially significant are substitutability elasticities, which determine the substitutability of domestically produced and imported goods for different users (import substitutability elasticities) and labor or capital substitutability elasticities.

Flexibility of substitutability should be defined for all goods and sectors. One approach is to use IO tables for a longer period and calculate values using econometric estimates. Due to the relatively short time series, the calculations were performed for only a few industries to get an idea of the size of the elasticities. Theoretically, micro-level data (company data) could also be used, but in practice this is difficult to implement because, for example, prices at company level will not be available and assumptions will still have to be made.

In the current version of the model, the elasticities of substitutability are determined by a combined approach (calculations, values from the literature and calibration), additionally assuming that it will be the same for all users. The most important factor in determining the choice of values is the substitutability of the product and the availability of the domestic product. For example, the elasticity of substitutability of domestically and abroad-produced fuel is very low, because Latvia does not have a domestic oil refining industry, but in another case - for example, food and beverages - the elasticity of substitutability is high. The most difficult is to identify the most appropriate value of the elasticity of substitution for sectors where the goods produced are very homogeneous (e.g. the case of chemicals and products). Similarly, the flexibility of labor and capital substitutability is determined - taking into account the particularities of the production process in the sector. The highest values of substitutability elasticity were set in the services sector, while the lowest in the manufacturing and energy sectors.

Note:

The integration of the estimated coefficients into the model still requires additional testing, which is still ongoing. A meeting with the Bank of Latvia experts is planned in order to assess the values of the elasticity coefficients and their potential changes, thinking about future forecasting.

Currently, it is the parameter matrix that is being worked on the most, because the values collected in it significantly change the assumptions about the behavior of economic agents used to determine the general equilibrium through optimization procedures.

Calibration of parameter values is also used to test the association with the TIMES model.

Simulations

Computable general equilibrium models can be used to study the effects of different policy measures on the economy in general, as well as on individual sectors.

The simulations are based on hypothetical scenarios, which are identified as changes (shocks) of individual exogenous variables. Initially, a baseline scenario is developed, which usually relies on the assumption of the stability of current trends, market developments without the impact of additional external shocks. The baseline scenario is generally in line with the most plausible developments. Only when the calibration results correspond to the proposed baseline scenario the effects of specific measures on the overall balance can be studied.

The aim of the complete CGE model is to provide an opportunity to perform simulations, creating shocks and estimating absolute and relative changes in the variables of interest - both at the macro level - GDP and its components, and by sectors.

In simulations, shocks can be applied to different magnitudes, making it possible to use general equilibrium models for different purposes and to study and analyze possible economic development and the effects of changes in various factors in different ways. The simulation relies on the fact that there are more variables than equations in the model and evaluating the model requires the user to choose which variables will be exogenous. Shocks can be obtained only for exogenous variables.

Thus, in the CGE model, shock identification means indicating which variables will be exogenous and may be "shocked" while identifying others as endogenous. The variables are also chosen depending on the assumption of the duration of the shock effect. The CGE model distinguishes between short-term and long-term shocks. This is related to the ability of market participants, as well as the economy as a whole to adapt to specific changes. Short-term closure assumes that there is a sufficient time for prices to change, substitution due to price changes occurs, but investment decisions that could significantly change the amount of capital in the sectors are not yet affected. This is due to the fact that such capital investments (new buildings, equipment, their purchase and installation) are a time-consuming process and long-term.

Traditionally, in the short run, the endogenous variables are employment, return on capital, foreign trade balance and gross domestic product. Accordingly, real wages, technological changes in primary production factors, capital, private consumption, investment and government expenditure are exogenous.

Table 1 and Figure 4 include variables that could potentially be used for short-term shock simulations.

Table 1

Variables used to generate short-term shocks in the ORANI-G model

Exogenous variables constraining real GDP from the supply side	
x1cap x1lnd	industry-specific endowments of capital and land
a1cap a1lab_o a1lnd a1prim a1tot a2tot	all technological change
f1lab_io	real wage shift variable
Exogenous settings of real GDP from the expenditure side	
x3tot	aggregate real private consumption expenditure
x2tot_i	aggregate real investment expenditure
x5tot	aggregate real government expenditure
f5	distribution of government demands
delx6	real demands for inventories by commodity
Foreign conditions: import prices fixed; export demand curves fixed in quantity and price axes	
pf0cif	foreign prices of imports
f4p f4q	individual exports
f4p_ntrad f4q_ntrad	collective exports
All tax rates are exogenous	
delPTXRATE f0tax_s f1tax_csi f2tax_csi f3tax_cs f5tax_cs t0imp f4tax_trad f4tax_ntrad f1oct	
Distribution of investment between industries	
finv1(selected industries)	investment related to profits
finv2(the rest)	investment follows aggregate investment
Number of households and their consumption preferences are exogenous	
q	number of households
a3_s	household tastes
Numeraire assumption	
phi	nominal exchange rate

For creating a short-term closure, the following amply scheme should be used; rectangles denote short-term fixed values, and ovals - endogenous values (they change).

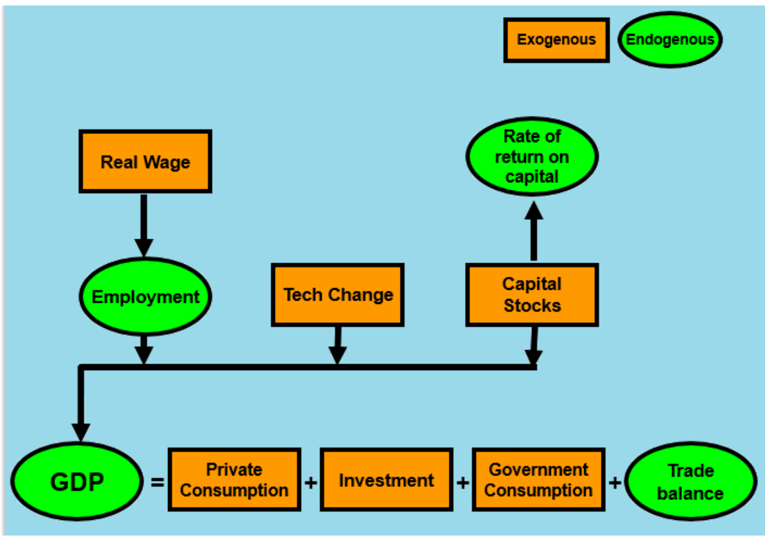


Fig. 4. Basic assumptions for short-term shocks on variable exogenicity and endogenicity

Table 2 lists the variables that could potentially be used for long-term shock simulations. In the long run, economic agents have enough time to make investment decisions, shifting capital from one sector to another. Consequently, in the long run, the amount of capital changes, keeping only the amount of return on capital fixed. The amount of total employment is also fixed, but real wages are changing. In the long run, it is assumed that real household final consumption expenditure and real government expenditure are linked and modeled together.

Table 2

Variables used to generate long-term shocks in the ORANI-G model

Exogenous variables constraining real GDP from the supply side	
gret	***gross sectoral rates of return***
x1lnd	**industry-specific endowments of land**
a1cap a1lab_o a1lnd a1prim a1tot a2tot	**all technological change**
employ_i	***total employment - wage weights***
Exogenous settings of real GDP from the expenditure side	
delB	***balance of trade/GDP***
invslack	***aggregate investment determined by industry specific rules***
f5tot2	***link government demands to total household***
f5	**distribution of government demands**
delx6	**real demands for inventories by commodity**
Foreign conditions: import prices fixed; export demand curves fixed in quantity and price axes	
pf0cif	**foreign prices of imports**
f4p f4q	**individual exports**
f4p_ntrad f4q_ntrad	**collective exports**
All tax rates are exogenous	
delPTXRATE f0tax_s f1tax_csi f2tax_csi f3tax_cs f5 f5tax_cs t0imp f4tax_trad f4tax_ntrad f1oct	
Distribution of investment between industries	
finv3(selected industries)	***fixed investment/capital ratios***
finv2(the rest)	**investment follows aggregate investment**
Number of households and their consumption preferences are exogenous	
q	**number of households**
a3_s	**household tastes**
Numeraire assumption	
phi	**nominal exchange rate**

For the long-term closure, the following amply scheme should be used, in which rectangles denote short-term fixed values, and ovals - endogenous values (they change). In the long run, exogenous variables are employment, technological change in primary factors of production, return on capital and foreign trade balance. Real wages, capital, gross domestic product, private consumption, investment and government spending remain endogenous.

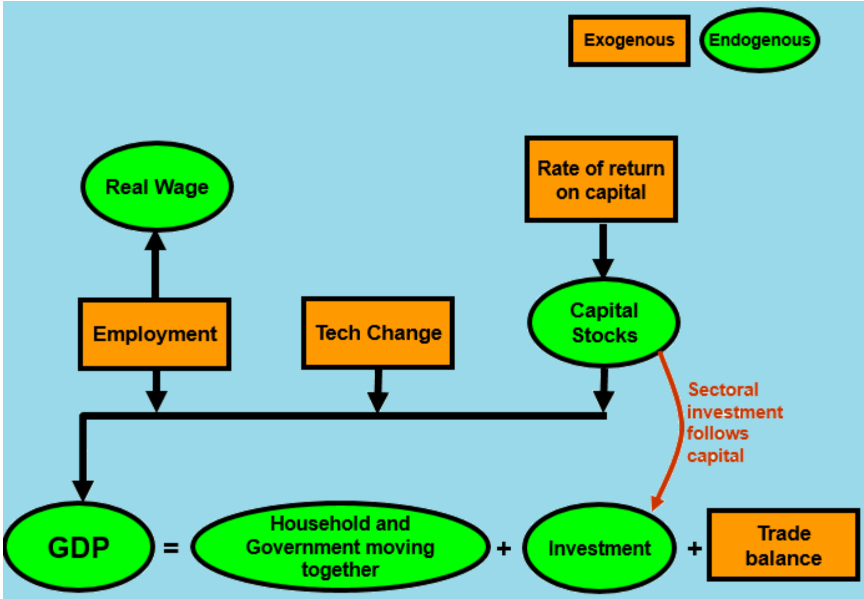


Fig. 5. Basic assumptions about long-term shocks for variable exogenicity and endogenicity

The results of the static CGE model can be interpreted as a change in the variable "some time after shock". The use of CGE models starts with defining a pre-policy framework where simulations are performed to determine post-policy effects. The base is constructed using base year data (i.e., before policy) to identify exogenous variables in the model (setting model equations and behavioral parameters for the data). This means, that the model is designed for modeling the impact of a shock on the current economic structure, which is considered to be a stable or balanced position.

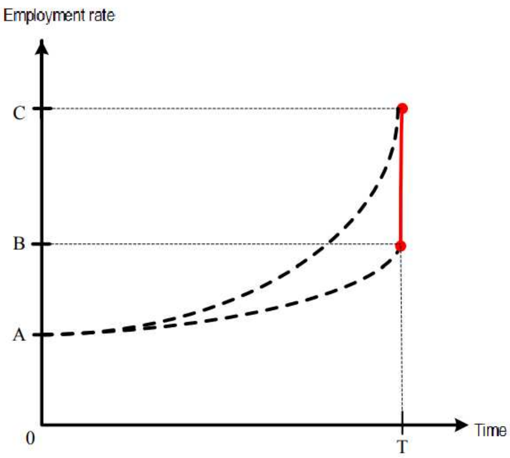


Fig. 6. Example of interpretation of static CGE model results

Figure 6 shows the result of the simulation or shock to a specific variable (e.g., employment rate). ***A*** denotes the level of the variable of interest in the reference period (0), ***B*** denotes the level that would have been reached at time T if all influencing factors stayed unaltered, and ***C***, in turn, shows the projected level if certain policy measures had been introduced in the reference period (). The CGE model table shows the results of percentage change $\frac{(C-B)}{B} \times 100.$

In Figure 6, the time period T on the horizontal axis is not fixed. In the literature, short-term shocks are usually associated with effects of up to 2 years, long-term shocks are based on the assumption that the economy has enough time for economic agents to change their investment decisions.

Due to the CGE's ability to model the impact of various factors, structural or market changes, computable general equilibrium models are successfully used in the analysis of economic shifts and economic policy decision-making. The computable general equilibrium model can be implemented in the analysis of various external shocks (changes in import and export prices, changes in foreign investment, changes in the purchasing power of households, changes in production and technology, etc.).

By creating a link between the CGE and TIMES models, it becomes easier to identify very specific energy policy measures in the TIMES model, so the iterative process starts with the TIMES model. For simulating a scenario corresponding to the chosen plan of measures, the results of the TIMES model (Excel file) are used to quantify changes in energy balance, instrumental variables for identifying the respective shock are selected, the relative changes of these variables are calculated and entered into the CGE model.

The *tablo* file is very large, that's why model's compression is usually used to perform the simulation. We use two methods: either in the ORANIG_LV.TAB format file it is indicated which variables are exogenous, which are endogenous and the simulation in the compressed Stored-input file (ORANIG_LV.SIT) file is performed; or OMIT, SUBSTITUTE, and BACKSOLVE commands in the TAB file are applied.

The results of the CGE model show changes in the equilibrium values for various variables, including energy demand, which in turn are returned to the TIMES model as values for exogenous variables.

In the process of soft linking user controls the transfer of information from one model to another, evaluates the results of one model, decides whether and how they should be modified for achieving convergence of the two models. As Helgesen (2013) concludes in his study, the advantages of soft tying could be: utility, transparency, and model training. Current CGE and TIMES linking simulation is still in the "training" phase. The first lesson was an understanding of the need to calibrate substitutability elasticities and the size of the model.

Validation

In order to make sure that the developed Latvian CGE model performs calculations correctly - in accordance with economic theory and data - model validation is required. The validation procedure is based on the recommendations of Dixon & Rimmer (2013).

Several procedures are used for the validation of the Latvian CGE model. The first test in model validation involved checking the identities of national accounts to ensure that they were valid with existing input data. Nominal and real GDP values were used in this procedure. Simulations that correspond to real economic events in the period after the base year were also tested. So, creating simulations, the results of which we know a priori. Tests were performed using already known values of exogenous variables to ensure that the predicted values of endogenous variables in the model were close to the actual observations.

2. LINKING CGE AND TIMES MODELS

2.1. Literature Review

It is popular to use a combination of bottom-up and top-down models in energy policy development and decision-making. (Krook-Riekkola et.al., 2017) describes the experience in Sweden, where a combination of TIMES model and CGE model (soft-linking) is used to model energy and climate policy. The authors have described in detail the challenges of providing such a link and offer valuable advice. One of the most significant benefits mentioned (Krook-Riekkola et.al., 2017) from the interaction between the two models - detailed modeling of energy-intensive industries in both TIMES and CGE and information exchange between the two models at an early stage, helps to ensure convergence of both models faster. Soft-linking also has a weak point - it is a time-consuming procedure, as many comparisons are carried out manually.

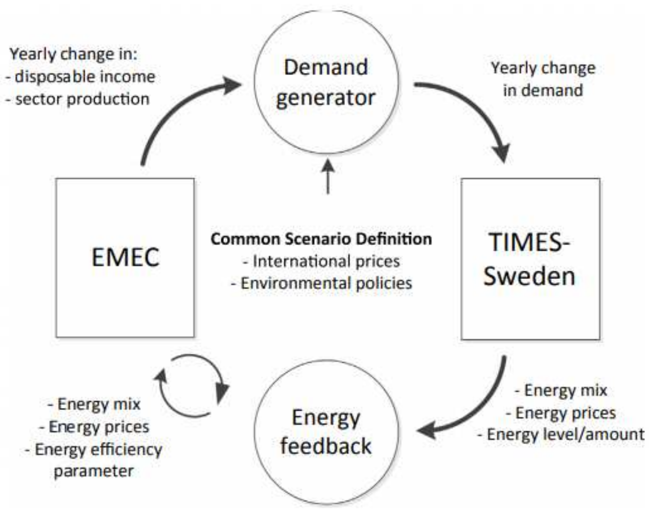
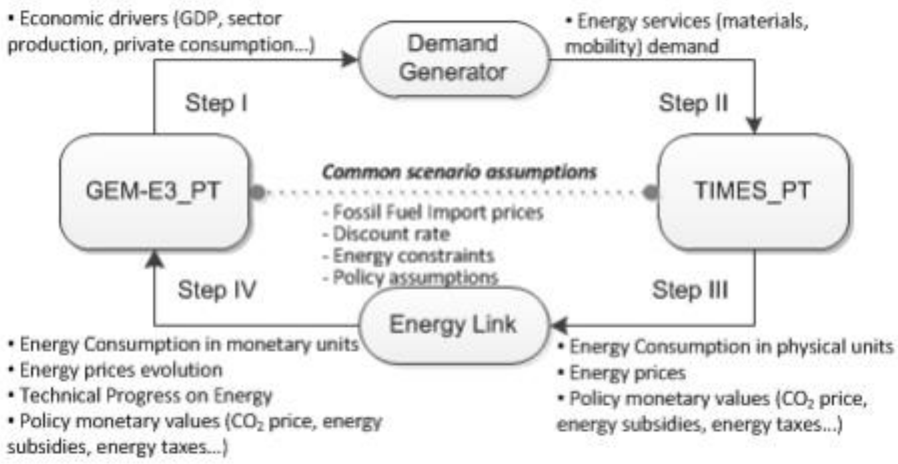


Fig.7. Swedish experience in linking TIMES and 1-period recursive CGE models

Another example is the experience of Portuguese researchers in linking the general equilibrium model and the TIMES-type model (Fortes et.al., 2014). Figure 8 shows the information flow in several steps between the two types of models.



8 fig. The approach used by Portuguese researchers to link the TIMES and CGE models is a hybrid platform [6]

Both (Fortes et.al., 2014) and (Krook-Riekkola et.al.m 2017) describe in detail, step by step, in what way the results of one model can be applied to evaluate another model. The authors emphasize in particular that successful interaction is based on the development of a common calibration scenario.

The case of Latvia is not an exception, and in order to create the best possible link between the CGE and TIMES models, a way must be created for exchanging information between models as efficiently as possible, without it successful interaction between the two models is not possible.

2.2. Latvian CGE and Times Soft- Linking

Summarizing the best experience, we conclude that the most successful results, suitable for political decisions, are not based on the implementation of only one - CGE or TIMES model. However, establishing and maintaining such a link is a huge challenge for researchers.

One of the key questions is - how to identify the points of contact between the two models? A link is formed when an endogenous variable from one model is inserted into the other model as exogenous (fixed). In the CGE model, it is possible to change the status of one variable from endogenous to exogenous and vice versa, as long as the identification conditions are maintained (sufficient number of equations to estimate the unknowns). On the other hand, CGE is a top-down model and its possibilities for adapting to another model are not infinite. According to the experience of Sweden or Portugal, we calculated that it will be necessary to convert the obtained information

[6] Fortes, P., Pereira, R., Pereira, A., Seixas, J., 2014. Integrated technological-economic modeling platform for energy and climate policy analysis. Energy Vol.73, p.716-730

into a format necessary for the other model when working in Excel. The following is a brief description of the current version of the link, as well as the problems identified that still need to be addressed.

A correlation matrix A is created between Times-end-consumption level 3 and Input-Output table industries (NACE Rev. 2) by product use (CPA * 64) in 2 categories - 'Coke and refined petroleum products' (V19) and 'Electricity, gas, water, steam and air conditioning '(VD).

The matching matrix (A) is supplemented by the variable ‘Industry group’, according to the assumptions of the CGE model.

Further calculations are made at the ‘Industry Group’ level.

Step 1:

Based on the Times-end-consumption data, the average annual growth rates of the 'Industry Group' energy demand scenario are calculated.

$$\boldsymbol{dTCn = (TC2050/TCto)^{(2050-to)} - 1}$$

where

to - base year

dTCn - average annual growth of energy demand in a given period

TC2050 - energy demand forecast in 2050

TCto - energy demand in the base year

The average annual increase in energy demand is assumed to be an energy demand shock to be added to the CGE model according to the TIMES scenarios.

Step 2:

Input-output tables for 2016 are used to calculate output-input ratios by industry.

The output side of the output / input ratio does not include output attributable to Coke and refined petroleum products and Electricity, gas, water, steam and air conditioning supply, in other words energy as a by-product.

The output / input ratio is further divided into 2 components by product of input: the output / input ratio component ‘Coke and refined products and Electricity, gas, water, steam and air conditioning’, and the output / input ratio component ‘Other products’.

Output-input ratio = (Output at basic prices - R19 - RD) / Total input

Where

R19 - Coke and refined petroleum products

RD - Electricity, gas, water, steam and air conditioning supply

Output-input ratio = (Output-input ratio EN -1) + (Output-input ratio OTH -1) +1

where

EN - refers to the contribution of energy products to the output-input ratio

OTH - refers to the contribution of non-energy products to the output-input ratio

The energy demand shock is realized through the first component Output-input ratio EN, assuming that in the short term the non-energy component, (Output-input ratio OTH, is fixed.

Step 3

To transform an energy demand shock into an comprehensible CGE, it needs to be transformed into a change in the GDP of the 'Industry Group'. This is obtained by calculating the relative increase in the output-input ratio: if the energy demand shock versus the shock-free ratio is applied.

Industry group output (GDP) growth =

((Output-input ratio EN -1) * (1+ dTCn) + (Output-input ratio OTH -1) +1) / ((Output-input ratio EN -1) + (Output-input ratio OTH -1) +1) -1

or

Industry group output (GDP) growth =

Output-input factor EN * dTCn / Output-input ratio

These assumptions ensure that the relationship between sectoral output growth shocks and the output-use ratio is inversely proportional, but variations at close output-input ratios depend on the sector's energy dependence. This transition is shown more clearly in Figure 9:

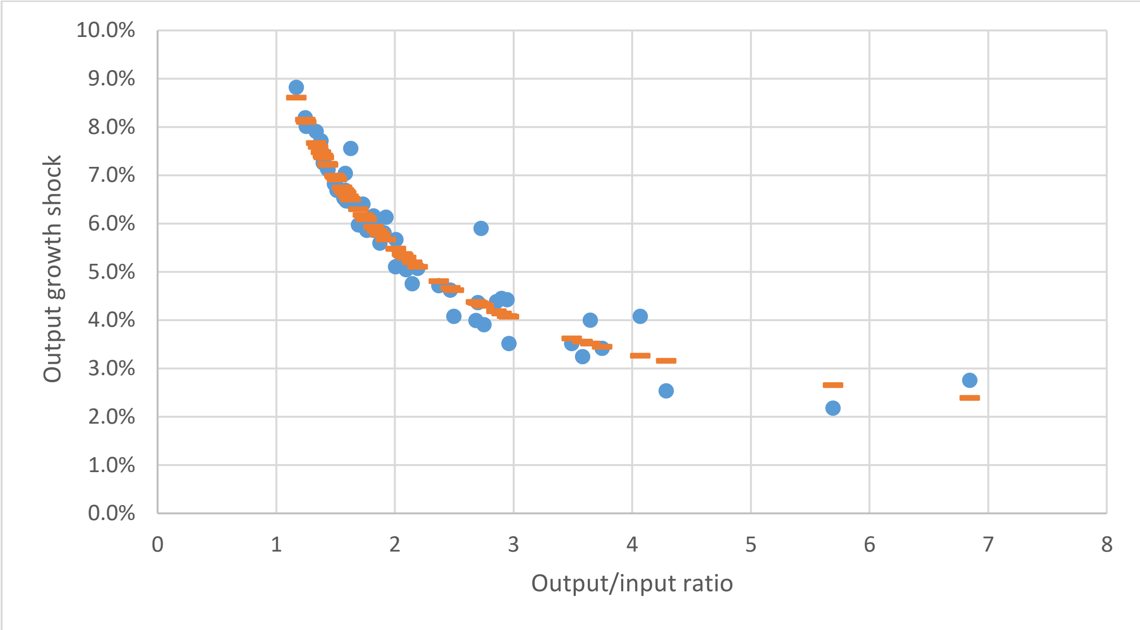


Figure 9. Output growth shocks in economic sectors with equal changes in energy demand (10%)

As can be seen, the output growth shock of the Industry Group (GDP) depends directly on the share of energy input in the sector, and it is just logical that the effect of the energy demand shock is greater in sectors with higher energy consumption. (See Figure 10 for a diagram.)

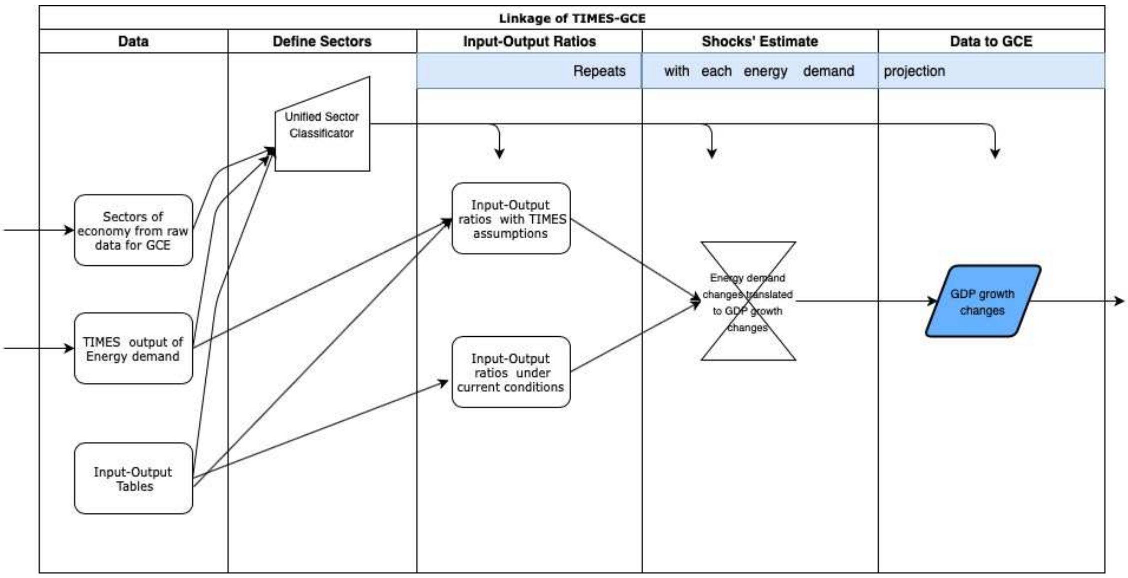


Fig. 10. Soft -linking scheme of CGE and TIMES models

Figure 10 shows one stage of one iteration of the connection of both models. When a soft- link between CGE and TIMES models are set up, all necessary calculations are performed in an Excel file (see appendix)

In practice, this means the need to develop criteria that would allow modeling experts to decide that the iteration process is complete.

3. CONCLUSIONS AND NEXT STEPS

3.1. Key Findings

- The CGE model developed in the study is an adaptation of the ORANI-G model formulated by Horridge (2014) to the Latvian economy. GEMPACK software is used to evaluate the model.
- The CGE model is based on symmetric input-output tables for 2015 (Source: csb.gov.lv).
- Parameters such as substitutability elasticities have been determined as a result of calibration, with initial values estimated partially by econometric modeling and partially from the scientific literature. In doing so, the substitutability of the product and the availability of the domestic product have been taken into account. The refinement of the parameter values is still ongoing, given the need to link to the TIMES model.
- There are different forms of linking CGE and TIMES models. Currently, we have moved from completely separated models (two separate operating models) to the creation of a functioning soft- link - the points of contact between the two models have been identified, formulas for converting the results of one model into input data of the other model have been developed, and convergence criteria are being developed.
- As Helgesen (2013) concludes in her study, the advantages of soft-linkung could be: practicality, transparency and model training. The current link between CGE and TIMES for simulation is still in the "training" phase, which identifies advantages and opportunities as well as challenges.
- Taking into account the crisis caused by Covid-19 in the world and in Latvia, a number of indicators need to be re-evaluated in order to update the current economic developments and integrate them into the model.

3.2. Proposals for the Improvement of the CGE Model and the Connection Between the Two Models

- The developers of TIMES and CGE models must agree on the development of iteration convergence criteria in a form that is not as complicated and time-consuming as Krook-Riekkola et al. (2017), but would not be based solely on the subjective opinion of the researchers themselves.

- Discrepancy between base years, assumptions about the stability of Latvia's economic structure and cost structure, in order to consider that 2015 does not differ significantly from 2017, in the static form of the CGE model without a time dimension - these are problems that need to be addressed in the near future.
- As already mentioned in the introduction, it is planned to create a recursive form of one period for the improvement of the general equilibrium model developed by LU researchers (if necessary, recursion of several periods could be used, but the experience of Swedish researchers shows that good results can be achieved with one period recursion only).
- An alternative model is being considered to address the time dimension mismatch. In the TIMES model, projections are made until 2050, while in the CGE model, the only assumptions over time are: short-term shocks or long-term shocks. Thus, by choosing an EU country that was some time ago at a similar stage of development as Latvia is now, one could choose the input-output structure of this country as the economic structure of Latvia's "Future", for example, the 2030 equilibrium prototype. Helgesen (2013) described the idea of the future balance of the CGE in the connection with TIMES in his study of Norway.
- On the basis of the latest economic developments due to COVID-19, the question of the consistency of the interpretation of economic results with the latest economic trends should be addressed.

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APPENDIXES

Appendix 1: List of Latvian CGE sectors

1) Agriculture
2) Forestry
3) Fishing
4) Wholesale and retail
5) Schools, universities, research
6) Medical
7) Culture, entertainment, sports
8) Other Commercial
9) Transport
10) Chemical and chemical products
11) Non-ferrous metals
12) Non-metallic minerals
13) Food and tobacco
14) Mining and quarrying
15) Machinery
16) Paper, pulp and print
17) Wood and wood products
18) Construction
19) Other Industrial;
20) Residential