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How to model the impact of climate policy on the economy? Lessons from foreign experience

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Presentation outline

Start of the project: September 2021.

Two hypotheses at the beginning:

1. Computable General Equilibrium (CGE) model and its soft-link with the Integrated MARKAL-EFOM System (TIMES) model is effective way to assess the impact of climate policy on the economy;

- Literature review: why use CGE? any alternative linking methods? best practice examples.

2. The present version of the CGE model owned by the University of Latvia is appropriate to achieve this aim.

- Review the features of the present version of Latvian CGE model (developed by the University of Latvia during the previous project), compared to its ORANI-G model prototype (for Australia);
- Propose a list of recommendations - a roadmap for the future development of the Latvian CGE model.

Why to use CGE (and not econometric) model?

- Diffenbaugh, Burke (2019) «Global warming has increased global economic inequality». *Proceedings of the National Academy of Sciences of the United States of America.*
- Finding: global warming is responsible for 25% increase of the income inequality between countries over the past half century.

$$\Delta \log(Y_{it}) = \beta_1 T_{it} + \beta_2 T_{it}^2 + \lambda_1 P_{it} + \lambda_2 P_{it}^2 + \mu_i + \upsilon_t + \theta_{1i} t + \theta_{2i} t^2 + \varepsilon_{it},$$

where Y_{it} is per capita GDP in country i in year t, T is the average temperature in year t, P is the average precipitation in year t, μ_i are country-fixed effects, υ_t are year-fixed effects, and $\theta_{1i}t + \theta_{2i}t^2$ are country-specific linear and quadratic time trends.

Or: GDP growth = f (Temperature, Rainfall)

- A critique by Rosen (2019) «Temperature impact on GDP growth is overestimated»:

«I believe that all of the numerical results cited in this article are wrong, because the methodology is not valid»

Excludes the main factors of economic growth: physical capital, population growth, technical progress, education, employment rate changes etc.

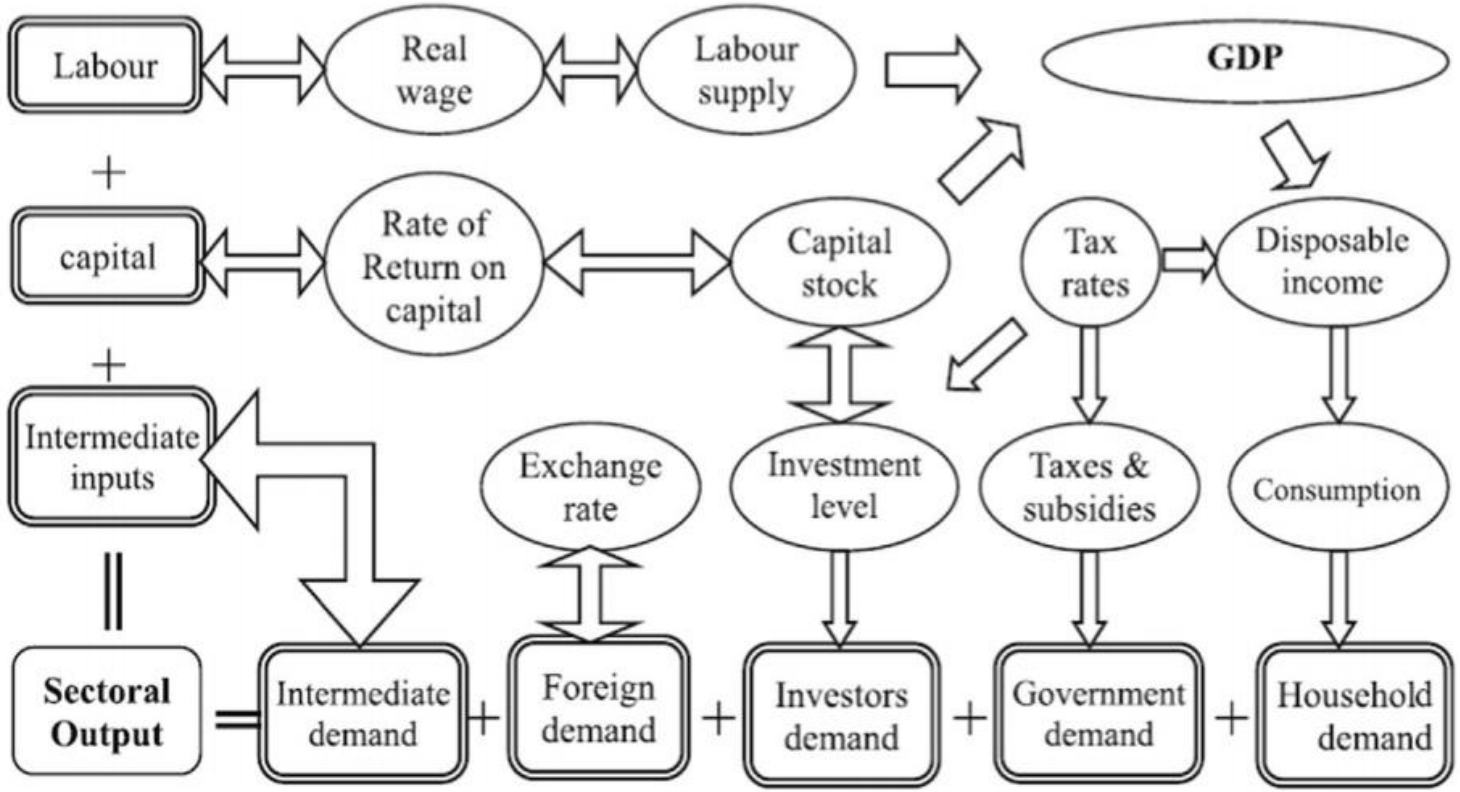
⇒Results based on one equation may be misleading.

It is not possible to describe all economic interactions in one equation.

CGE model is a computer simulation that uses a system of equations that characterises the interaction of all sectors of the economy. All these interactions should be considered to get reliable results.

CGE model consists of the 2 main parts:
(1) Model structure
(2) Database

CGE model structure:



CGE model database:

(1) income and expenditure flows in the economy (input-output tables, supply-use tables u.c.);

(2) parameter values.

Source: Babatunde, Begum, Said (2017). «Application of computable general equilibrium (CGE) to climate change mitigation policy: A systematic review». *Renewable and Sustainable Energy Reviews*, Volume 78, 2017, Pages 61-71, https://doi.org/10.1016/j.rser.2017.04.064.

Why one CGE model is not enough?

CGE model (University of Latvia)

«Top-down» approach:

- reflects the interaction of all sectors of the economy;
- assesses the impact of climate policies on non-energy sectors;

But does not pay attention to energy sector details:

- introduction of new technologies => Δ energy intensity;
- Δ energy demand => Δ energy mix;
- Δ competition => Δ electricity & heating prices.

Demand for energy

Energy prices, Energy mix

TIMES/MARKAL model (Institute of Physical Energetics)

«Bottom-up» approach:

- describes the energy sector in detail but do not include non-energy sector impacts.

Linking the two models would reduce shortcomings of each individual model.

«**Two-way soft-linking**»: each model works independently from each other (e.g., 1st model results are exogenous variables for the 2nd model). Two models are linked manually: information flows are controlled by researchers, in a form of multiple iterations.

How to link CGE with a bottom-up model (how will the models exchange information with each other)?

Soft-linking

- Models work independently;
- Information flows are controlled by researchers, in a form of multiple iterations;
- Transparency, researchers' learning-by-doing;
- Researcher decides how to change inputs/assumptions to get consistent results;
- Easier to develop, may be harder to use.

Hard-linking

- Models work independently
- information is exchanged automatically, using computer programs;
- Efficiency / productivity;
- Model 1 is given control over specific results; Model 2 may reproduce these results with a different aggregation level;
- Harder to develop, may be easier to use.

Hybrid model / model integration

- Models depend on each other
- Model integration may need to simplify one or both models significantly;
- OK for looking at a global picture, but with less sectoral or technological details, it is less useful for public policy considerations.

=> What this project will do: soft-link first, then think about hard-link.

Some of the best practice examples

Examples of linking the CGE and TIMES models

Article	Data sent from CGE to TIMES	Data sent from TIMES to CGE	Linking
Böhringer & Rutherford, 2009	• Energy demand	• Net energy output • Inputs of non-energy goods to the energy system	Hard-linking
Fortes, et al., 2014	• Energy demand	• Energy prices • Energy consumption • Policy monetary values	Integration
Dai, et al., 2016	• Energy demand	• Energy consumption	Soft-linking
Holz, et al., 2016	• Energy demand	• Energy mix	Soft-linking
Abrell & Rausch, 2016	• Electricity demand and price • Input prices for fuel, capital, labour, goods and services	• Electricity dispatch • Input demand for fuel, capital, labour, goods and services	Hard-linking
Krook-Riekkola, et al., 2017	• Energy demand	• Energy intensity parameter • Energy mix • Energy prices	Soft-linking
Wiebe, et al., 2017	• Energy demand	• Energy mix	Hybrid-linking
Andersen, et al., 2019	• Energy demand • Fuel prices	• Energy prices • Energy mix	Soft-linking

Source: authors' elaboration based on academic literature.

Overview of the current CGE model (owned by the University of Latvia)

- Latvian CGE model is static, based on Australian CGE prototype “ORANI-G” (its 2013 version “TPMH0110”).

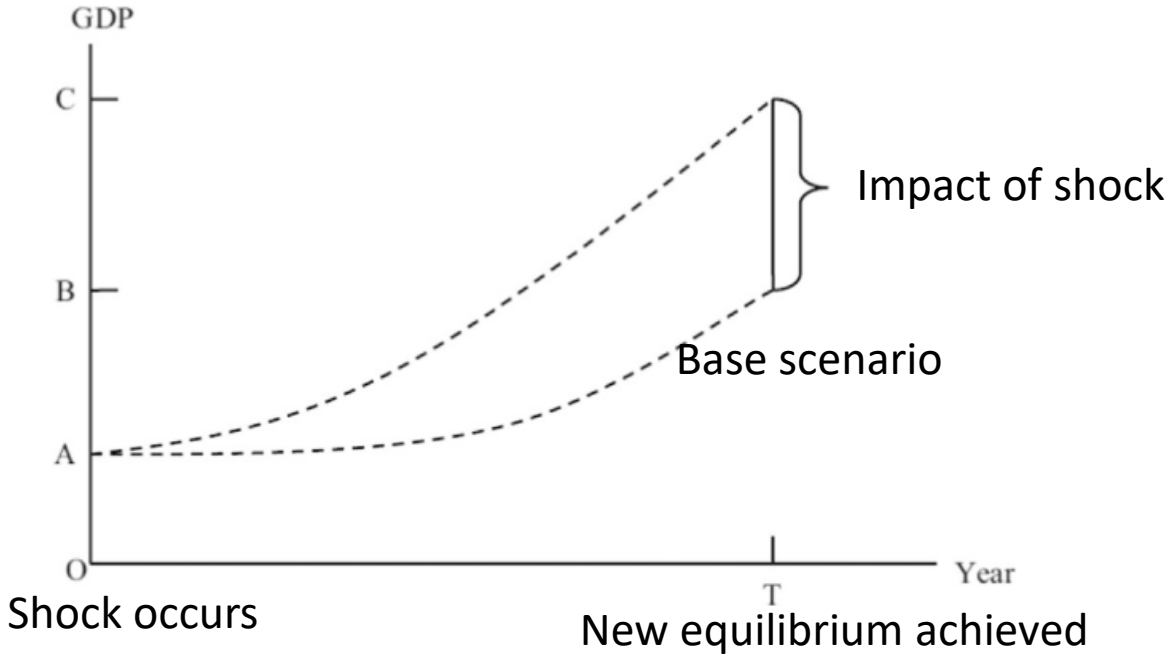
Some features of the current Latvian CGE model (compared to the ORANI-G):

- More detailed **sectoral structure**: 65 sectors in LV model vs. 37 sectors in ORANI-G;
- Employment (in each sector) divided by ISCO **occupation groups**: 10 groups in LV model vs. 8 in ORANI-G;
- **No regional breakdown**: Latvia is 1 region vs. 8 Australian regions in ORANI-G;
- All **equations** in LV model are identical to ORANI-G;
- Some **model parameters** in LV model differ from ORANI-G model (e.g., Armington elasticities*), but some are similar to ORANI-G model (e.g., Frisch parameter**).

* Armington elasticities: demand substitution between domestic and imported goods.
** Frisch parameter: total expenditure to discretionary expenditure ratio.

Limitations of the present version of the CGE model

- Static model – there is no dynamics => unable to assess how long (in years) it takes to reach a new equilibrium; observe only the final result (transition from old to new equilibrium is not observed); Two simulations are possible: "short-term" (physical capital exogenous) and "long-term" (physical capital endogenous);
- Carbon tax has not been introduced yet. An estimate of the increase in production costs due to rising CO_2 prices currently is based on expert judgement;
- Model structure (economy structure by sectors etc.) is not coordinated with a Bottom-Up model. Any soft-linking iteration would require additional calculations and assumptions.



- => We are going to **build a new dynamic CGE model** from a scratch (rather than trying to improve the current CGE model).

Why **dynamic** CGE model is needed?

- **CGE model types:**
- **Static CGE model (University of Latvia currently; ORANI-G)**: compares «equilibrium before shock» with «equilibrium after shock».

- **Dynamic CGE model**. Three reasons why we need a dynamic model:

1. Identify the economic forces that lead the economy to equilibrium;
2. Assess how long (in years) it takes to reach a new equilibrium;
3. Compare the dynamics of different variables after a shock.

- **Recursive-dynamic CGE model (ORANI - RD)**: dynamic alignment of a static model. Obtain solutions for each of many consecutive years: equilibrium solution for year «t» is used as a base for consecutive year «t + 1», without considering impact of economic agent's decision-making (economic agents have adaptive expectations);

- **Forward-looking dynamic CGE model:** Interconnected dynamic process, economic agents have perfect foresight and therefore react to future changes. When adding regional / sectoral dimension, CGE size grows exponentially => increase of computing time, difficult to achieve a convergence of a solution.

Conclusions

- Hypothesis 1 confirmed: Computable General Equilibrium (CGE) model and its soft-link with the Integrated MARKAL-EFOM System (TIMES) model **is effective way** to assess the impact of climate policy on the economy;

- Hypothesis 2 is not confirmed => we are going to **build a new dynamic CGE model** from a scratch (rather than continue developing the current version of the CGE model).

- Proposals:

1) Develop a dynamic version of the CGE model at the University of Latvia. It would allow comparing the behaviour of different macroeconomic variables by years;

2) Introduce a carbon tax in the Latvian CGE model. An estimate of the increase in production costs due to rising carbon prices should move from expert judgement to a model-based assessment;

3) Continue calibration of model parameter values for the case of Latvia (some parameter values are still the same as in Australian ORANI-G model);

4) Decide on which Input-Output matrix to base CGE model: a) 2015; b) 2020, which will be available at the end of 2023; c) employ supply-use matrix which is available annually (?);

5) An effective soft-link between CGE – TIMES/MARKAL models should be established by the LU – FEI. One of the links between the two models is GHGE matrix (on greenhouse gas emissions), which structure by sectors should be better harmonised between the two models.

Please address any comments and questions to:

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