The use of CGE models for climate mitigation analysis

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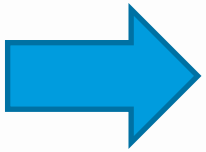
Why the use of models for analyze climate mitigation?

"Economics of Climate Change mitigation" is a strange field in economics since it relies heavily on modelling tools to assess economic impact of Climate Mitigation Policies (C.M.P). This is unusual, since the 90's empirical and historical methods dominate economics while modelling has slightly faded. Some tentative explanations:

- Climate Change (C.C.) is a very complex phenomenon, as well as its economic impacts:
  - Global and asymmetric shock across countries, sectors, agents and individuals.
  - Mix of demand and supply side impacts.
  - Dynamic issue: (if not mitigated) C.C. is a long run and permanent shock
  - Characterized by a lot of uncertainties (on temperature increase (Dietz,2011), on economic impacts (OECD,2015), on irreversible change and tipping points, Weitzman,2009)

Why the use of models for analyze climate mitigation (ctnd.)?

- But Climate Mitigation Policies (C.M.P) are not as less complex:
  - Climate change is a global externality → Government intervention at the heart of the action. Global: coordination issues and free-rider problems
  - Asymmetric impacts of C.M.P. and the fact that “winners” and “losers” of policy could differ from winners (if any) and losers of climate change.
  - Dynamic consistency of carbon pricing and other policies
  - Innovation and uncertainty



Need complex modelling tools to consider most of these elements and generally multiple models.
These models are designed to understand mechanisms, not to provide predictions.

What the specificities of climate change and climate policies lead to adopt modelling approaches

Climate Change and/or Climate Mitigation Policies will imply an expected structural change.

- Structural change (*i.e.,* changes in the sectoral composition of economies) is driven by change in production modes, preferences or (carbon) policy:
  - If no action → C.C. damages → lower labor productivity (heat waves), changes in yields, land losses (sea-level rises), change in energy demands,… → structural changes
  - If C.M.P. → decarbonization of economic systems → shift away from fossil-fuel to renewables, impact competitiveness of energy Intensive industries, promotion of energy savings (teleworking, building insulation,…), change in diet, changes in agriculture practices,… → structural changese benefits of action.

What the specificities of climate change and climate policies lead to adopt modelling approaches (ctnd.)

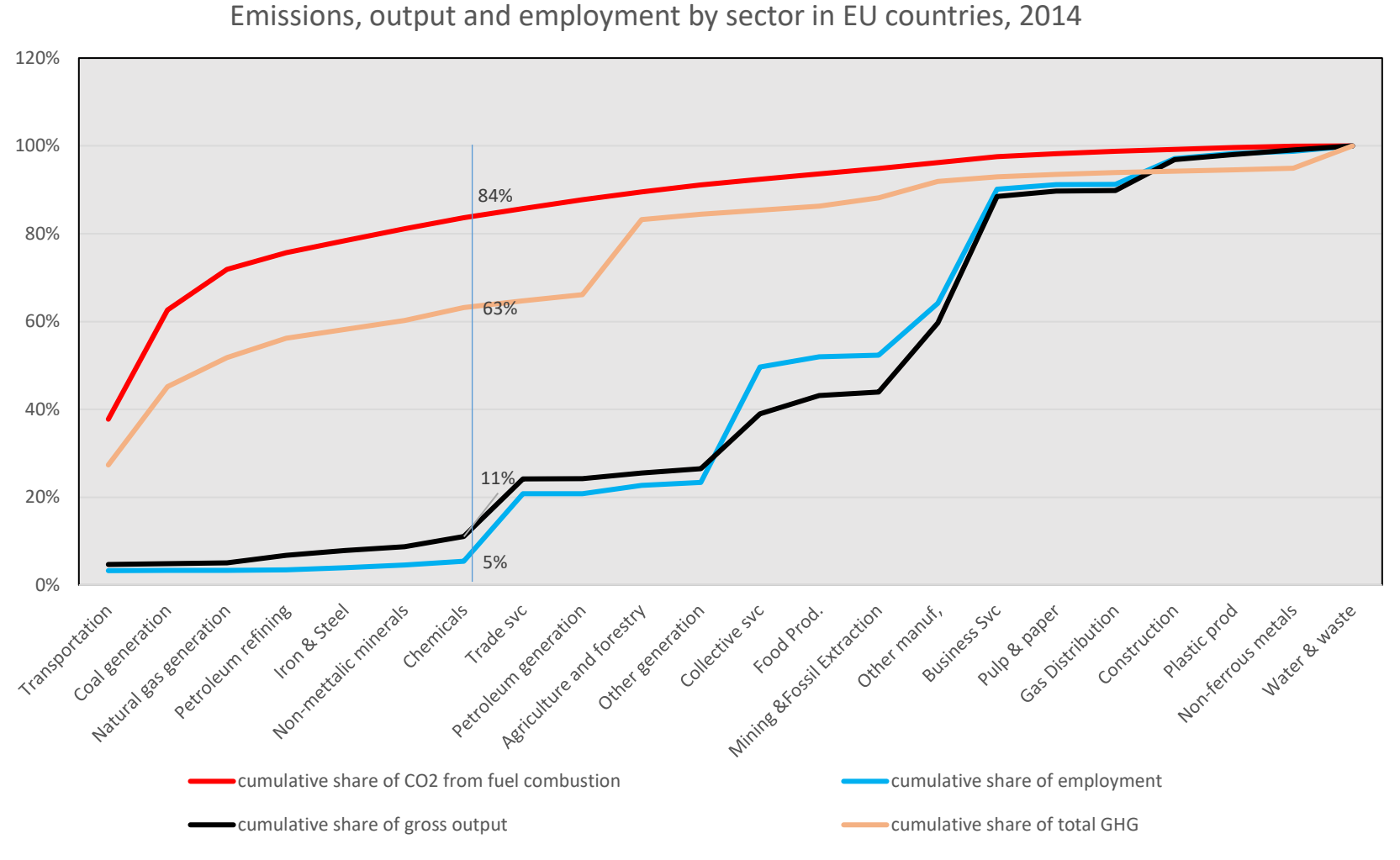
- Why this structural change is atypical:
  - Largely expected: this is historically unprecedent that we knows these structural changes will appear (ITC consequences were largely undergone, changes due to globalization were underestimated,…).
  - These changes are expected but no clear historical lessons (env. policies are not “new” but full system decarbonization are) → only few stylized facts → limits the use of empirical methods.
  - The structural change resulting from C.M.P. implementation is policy-driven with a central role for government.

→ Lead to a renew of ex-ante modelling analysis to “inform” policy officers of alternative choices and consequences of CMP vs no-action (CC damages).

→ The main policy challenge is the asymmetrical impacts of C.C. and/or C.M.P. on individual, countries, sectors,… especially since agents that will carry the burden of CC or CMP are not necessary enjoy more benefits of action.

Sector are differently exposed to CMP because their carbon content differ:

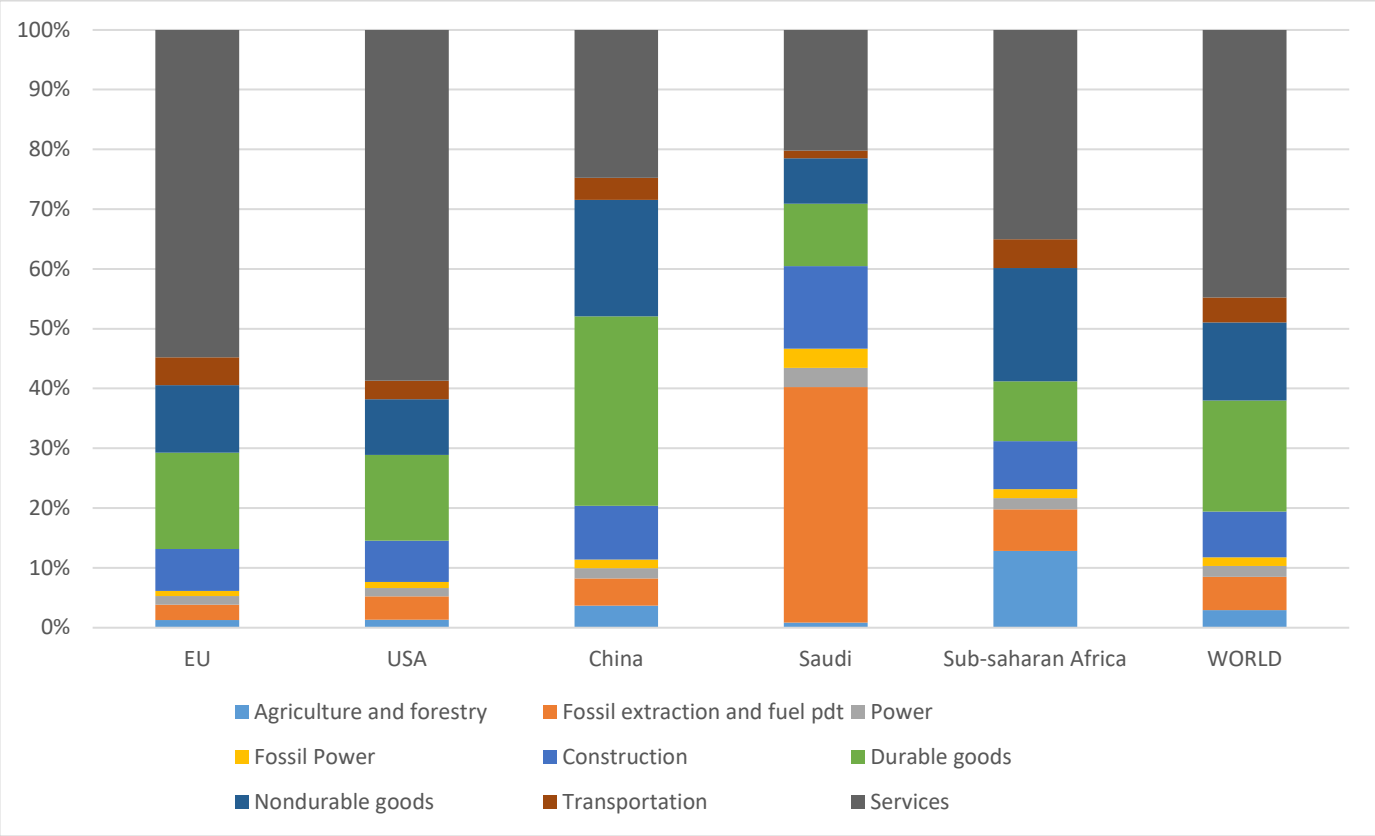
- The figure shows that only few sectors (energy intensive industries, fossil power and transport) are responsible for most CO2 emissions.
- These sectors are only a small part of the economy (5% of employment / 11% of output for 80% of emissions).
- If we account for all GHGs we must add agriculture to those sectors.



Source: Author calculation based on GTAP V10 Database, IEA energy balance, EDGAR database

Country are differently exposed to CMP because their economic structure differ

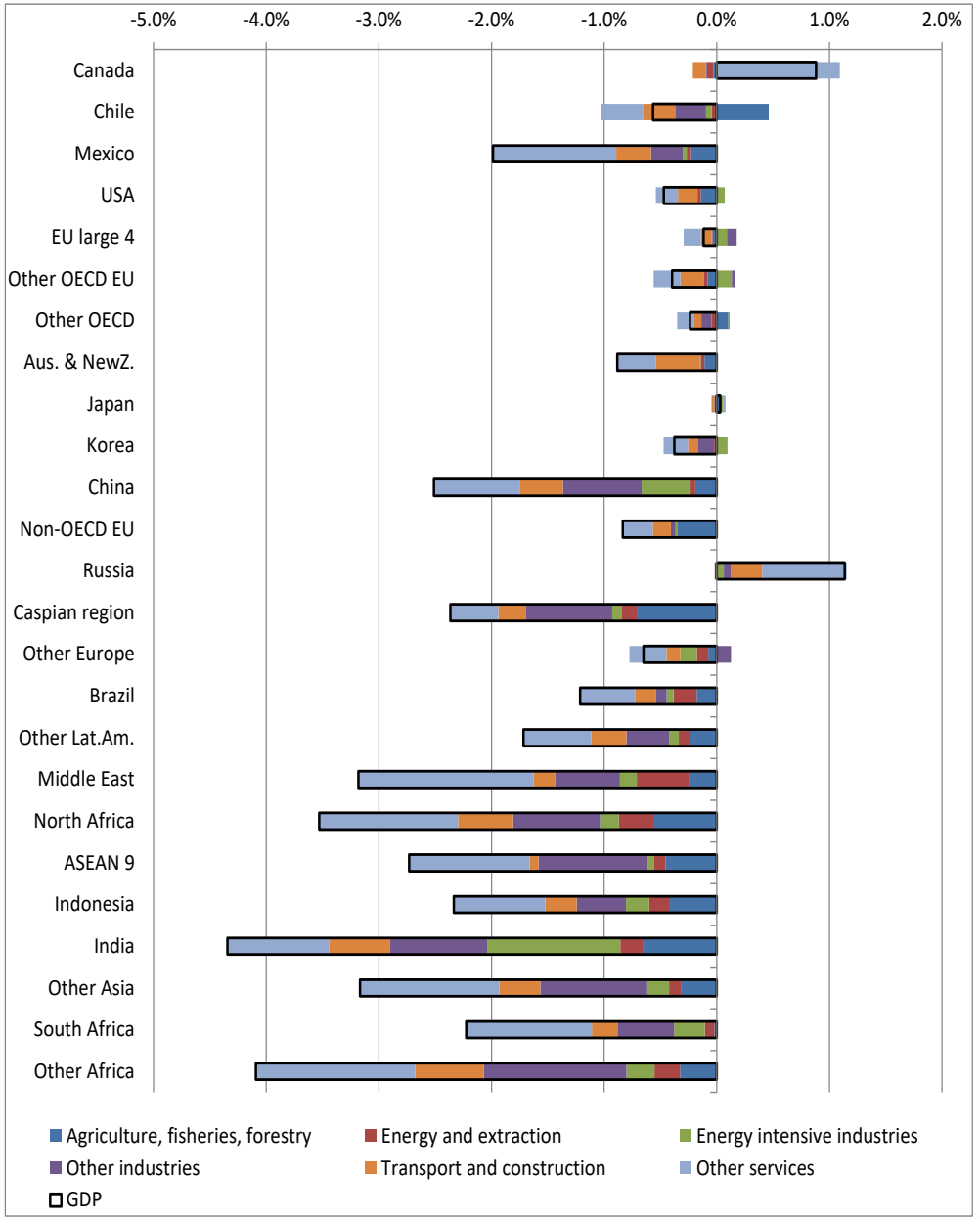
Sectoral composition of various economy in 2014: Sectoral value added by aggregate sector



Source: GTAP V10 Database

Climate change itself has differentiated impacts on sector and countries:

The figure presents the sectoral composition of damages from selected climate change impacts in 2050.
Here again we can see that country are not “equal” face to climate threat.
Moreover, the magnitude of sectors affected by climate damages is not at all the same across countries



Source: Economic consequences of climate change (OECD,2015).

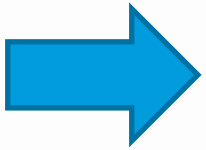
Different modelling frameworks for different purposes

We can classify modelling tools for assessing CMP and CC impacts:

- Top-Down or Macroeconomic Models:
  - Integrated Assessment Models (IAMs) – Economic Oriented : Nordhaus (1991) Tol(2002)
  - Computable General Equilibrium Models (CGE): GTAP, ENVISAGE/ENV-Linkages, GEM-E3 (next pres.).
  - Macro-econometric models: E3-ME
  - DSGE (Dynamic Stochastic General Equilibrium), Benjamin (next pres.)
- Bottom-up models:
  - Integrated Assessment Models (IAMs) – bio-physical Oriented: IMAGE, MESSAGE
  - Partial equilibrium: Economic models
  - Partial equilibrium: Engineering models (POLES, IEA-WEM, GLOBIOM)
- Hybrid Models (G-Cubed mix of CGE and DSGE)
- Economic models for distribution analysis: static DSGE, micro-simulation, ABM,…

What element economic models should integrate to deal with economic consequence of CMP?

- But for a comprehensive view of the economic impacts of C.M.P. models need to consider the following elements:
  - Structural change + asymmetric impacts of C.C. damages & C.M.P. across activities → need a sectoral model with a representation of economic flows (Input-Output).
  - Dynamic + importance of the baseline projection + medium-run & long run costs &benefits are different (transition costs, current investments with benefits delayed, local air pollutant benefits in medium run, …) → Need a dynamic structural model
  - Global perspective and trade impacts, the different costs of mitigation across countries and need of coordination, uneven distribution of natural resources → need a global model with explicit representation of different regions,



CGE models includes most of these elements

A bird-view of CGE Models and their applications to climate policy

A bird-view of CGE Models (1): Functioning and Model structures

- What is a CGE? → a Computable General Equilibrium model. Ok, but what this means exactly?
- Multi-sectoral models that describe how households, firms and government interact with each other on different markets (for commodity and factors).
- CGE are neo-classical models in their main features:
  - Households received income from selling production factors and maximize utility subject to income constraint to determine their consumption patterns.
  - Firms supply commodities and demand production factor in order to maximize profits subject to a constant returns to scale production function constraint
  - Prices adjust to balance demand and supply on all markets. Simultaneous equilibrium on all markets.
  - Non-competitive markets and other departures from first-best world could be added but these kind of distortion are generally limited in CGE models (imperfect competition in electric sector, real rigidities in labour and capital markets,…)

A bird-view of CGE Models (1): Functioning and Model structures (cntd.)

- Recap of main features of CGE models
  - They provide a description of the entire economy flows (or in case of multi-regional models all associated economies and trade flows) and are numerically calibrated with I-O tables/ SAM data (GTAP database for example).
  - Micro-economic foundations: description of entire Real economy through modelling of firms decision-making and household's behaviour (money is absent).
  - Generally, only representative agent (one firm by sector, one household,…)
- When dynamics these models are “recursive-dynamics”: like *Solownian* growth. Structural trends, no business cycles.
- Main drivers of the economic dynamic and economic response to policy shocks: primary factor supply, change in preferences & habits in time, relative price changes, factor productivity, energy efficiency improvements.
- In the CGE the links from economy to environment are straightforward and explicit:
  - Greenhouse gas (and air pollution) emissions are directly linked to economic activity.
  - Climate change & air pollution damages could be directly associated to the structural change drivers they affect (OECD, 2015,2016)

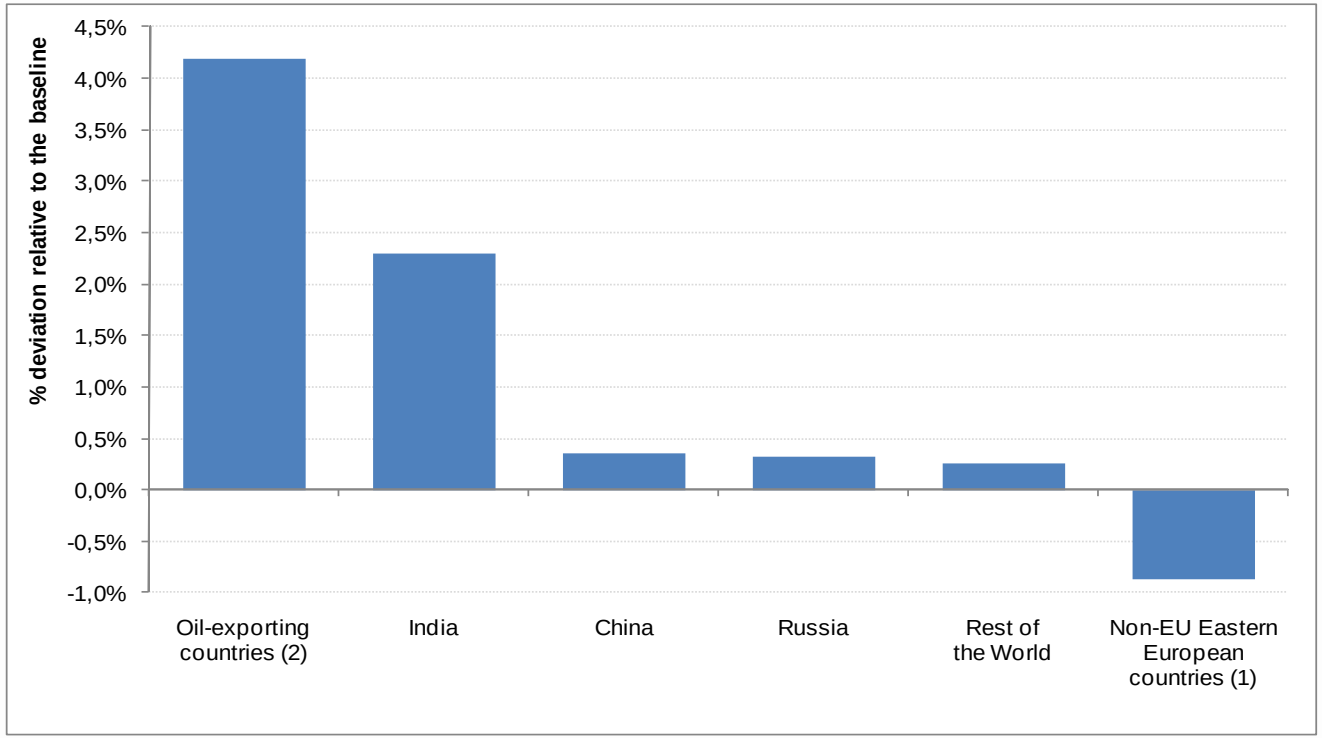
A bird-view of CGE Models (2): CGE models can analyze a wide range of C.M.P. instruments

- Market based instruments for C.M.P. :
  - Emission trading schemes
  - Carbon taxes
  - crediting (offsets),
- Other policy instruments:
  - Regulatory policy: command-and-control, emission standards,
  - Other fiscal instruments: household income taxes, tax subsidies on production factors to producers, excise taxes on product sales by agents, tariffs and export taxes (i.e. BCA),
  - government spending or incentives to private sector for R&D, etc…
- CGE models have full where and how flexibility:
  - Different policies can be assigned to different regions, sectors and greenhouse gases (e.g. ETS for CO_2 in energy-intensive industry & electricity, carbon tax on all other sources)
  - ETS can be global, multi-regional or for single region
- But CGE Models generally not able to assess current impacts of future policies : no forward-looking agents .

An illustration of use of CGE: Fossil fuel subsidies reforms

- Here a first example about phasing out fossil fuel subsidies.
- Assume that for efficiency or environmental purposes countries that have currently consumer fossil fuel subsidies want to phase them out.
- First assume that all country act unilaterally
- Most of countries that have in place FFS will record
- welfare gains (remove a distortion)

Unilateral Case : Impacts on Hicksian equivalent variation in income 2050 (% change from baseline).

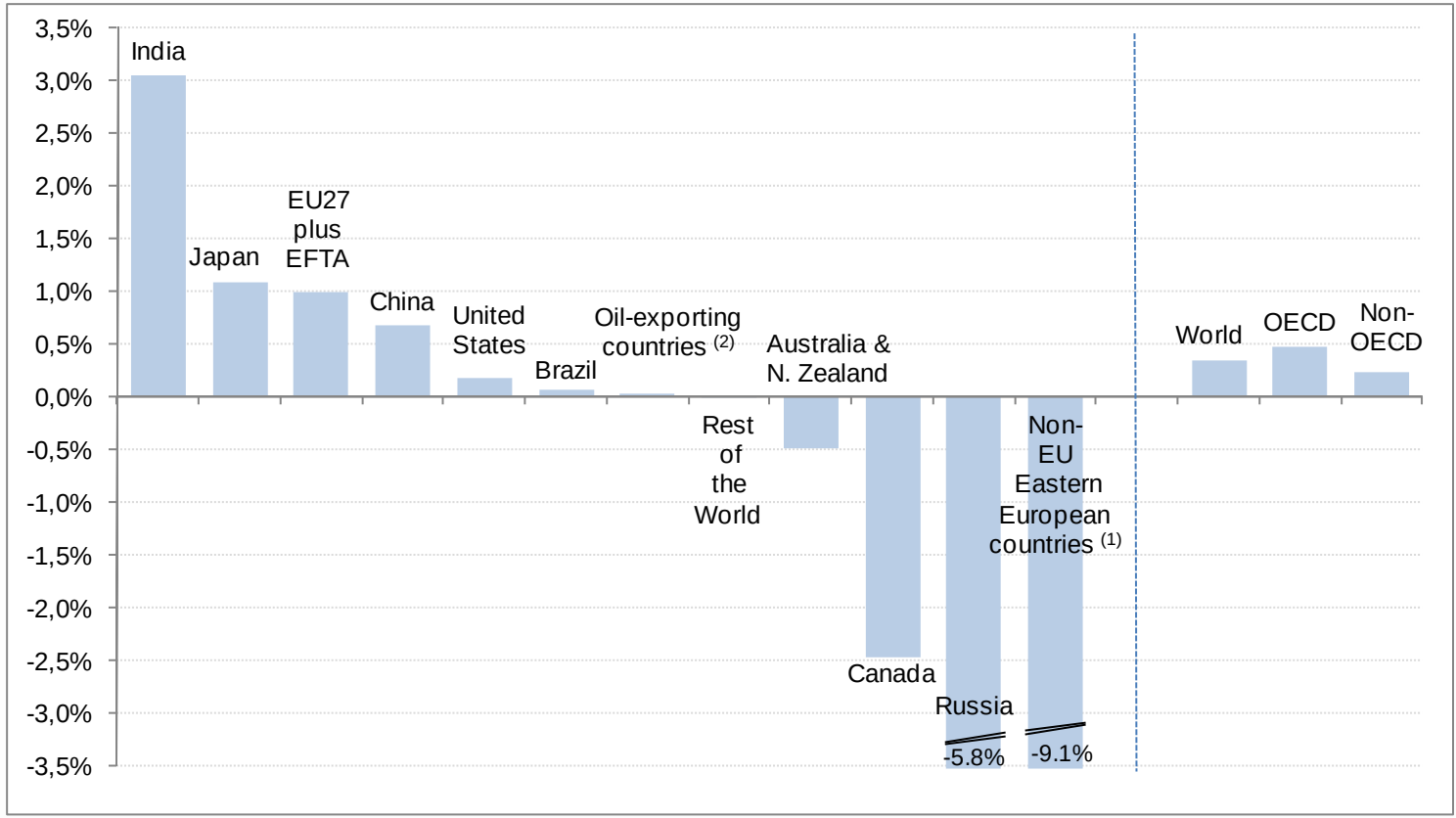


Burniaux & Chateau (2014)

An illustration of use of CGE (ctnd.) : with multilateral reform there may be losses in some countries

- Now assume that all country together remove their FFS subsidies.
- Some countries may loose while other win.
- Because now action has a huge impact on international
- market for fossil fuel → fall in demand → fall in prices → benefit for fossil importer but lost of oil rents for exporters
- International market / trade matters for assement of efficiency of energy policy.

Multilateral Case : Impacts on Hicksian equivalent variation in income 2050 (% change from baseline).



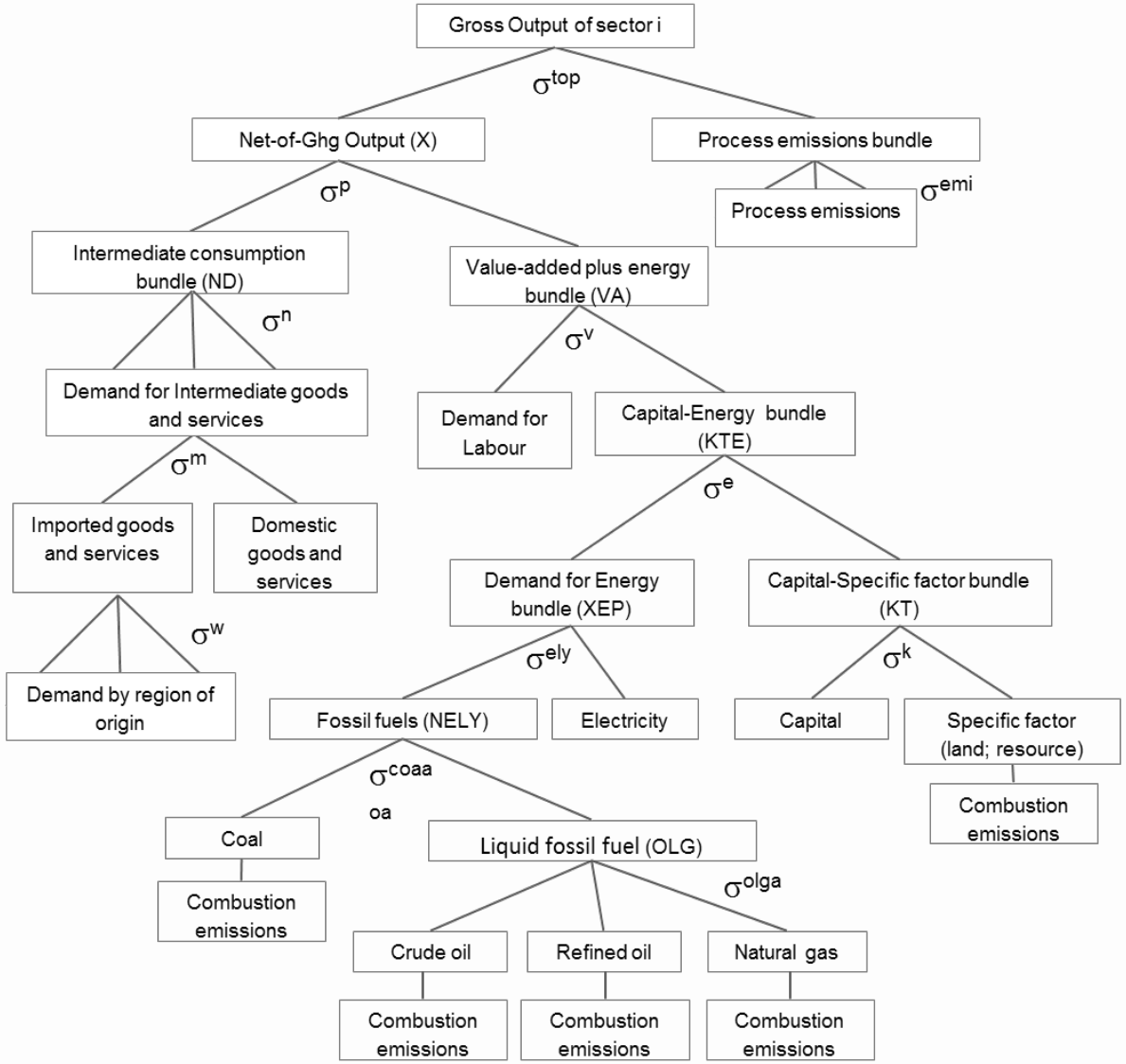
Burniaux & Chateau (2014)

Strengths of CGE models

- Most drivers of structural changes are explicit, and micro founded: help to understand economic impacts resulting from C.M.P.
- Heterogenous sectors and countries help to identify potential winners and losers, across sector, agents, countries.
- Accounting for impacts of C.M.P. (or CC damages) from other countries on domestic economies (through international trade of good and services) → international aspects is especially important for economies with energy-intensive structures, for fossil-exporters countries and for very open economy in general.
- CGE models are perfect tools for designing realistic economic "baseline" projections (for aggregate and sectoral variables) accounting for future structural changes (for aggregate and sectoral variables).
  - This is an asset for climate policy analysis because in practice some countries has submitted emission reduction pledges relative to baseline projection (like India).
  - Some countries also assume that part of their climate mitigation effort will be resulting form structural change away from heavy industries (like China see IEA, 2017).
  - But building a realistic baseline is a lot of work and not a straightforward exercise (see Fouré et al., Ho et al., Chateau et al.,2020 in the special issue of June JGEA)

CGE typically rely on production represented by nesting CES function

- Here is an example of production function in CGE (from the ENVISAGE or the ENV-Linkages models).
- This kind of CES nesting is very easy to handle but focuses most of criticism about CGE
- The main idea is to overlap a suite of CES to describe that substitution possibilities across factor and inputs are different.
- Substitution process could be different in short and long run.



Some weakness of CGE models

- Rigidities of the Input-Output structures of production & Trade structures (associated to CES functions) → limits the substitution possibilities in long run for the model to adapt to a C.M.P. → Problem for the Net Zero Emission scenario
- In the same spirit there is no obvious room for “apparition” of future commodities (hydrogen, nuclear fission) / mode of production. But there exist some solutions to make production structure evolve more smoothly (Rutherford, GEM-E3,…) or incorporate “back-stop” technologies.
- Financial markets and Investment-Saving behavior are simplistics and with myopic expectations. Babiker et al. (2009) showed that for long run issue forward looking behavior is not an essential difference with recursive dynamic, the problem is more the dynamic of financial markets.
- No money → not so important for long run issues like C.M.P.
- Model elasticities are rather poorly estimated and always never updated. → sensitivity analysis. New CGE models like Britz & Roson (2018) try to fix this issue.
- Fossil fuel (and natural) supply behavior is rather loose and still very important.
- Innovation and resulting input efficiency uses in the production processes are rather absent or ad-hoc.

Improving CGE models for climate issues

Option 1: Incorporate missing elements in CGE

- Integrating climate and air pollution damages in CGE → towards IAM (OECD, 2015,2016)
- Improve friction on factor markets → interesting but still complicate and rather ad-hoc (Chateau et al. 2018).
- Includes multiple households and agents in the framework → feasible but not really a priority (time and resources consuming), a better way is to link CGE with micro-simulation tools (see after).
- Improve domestic and international financial markets → feasible but ask for a lot of data (multilateral capital flows / accounting for multilateral debt/assets) and not so useful if the model still have no rational expectations.
- Improve representation of transition paths: neo-Keynesian elements, monetary rigidities, … → towards DSGE models.
- Improve representation of agriculture or/and energy systems, using information's from PE (partial equilibrium) models or from engineering models. Data issues / reconcilable volume and values → better to couple models (see after)
- ….

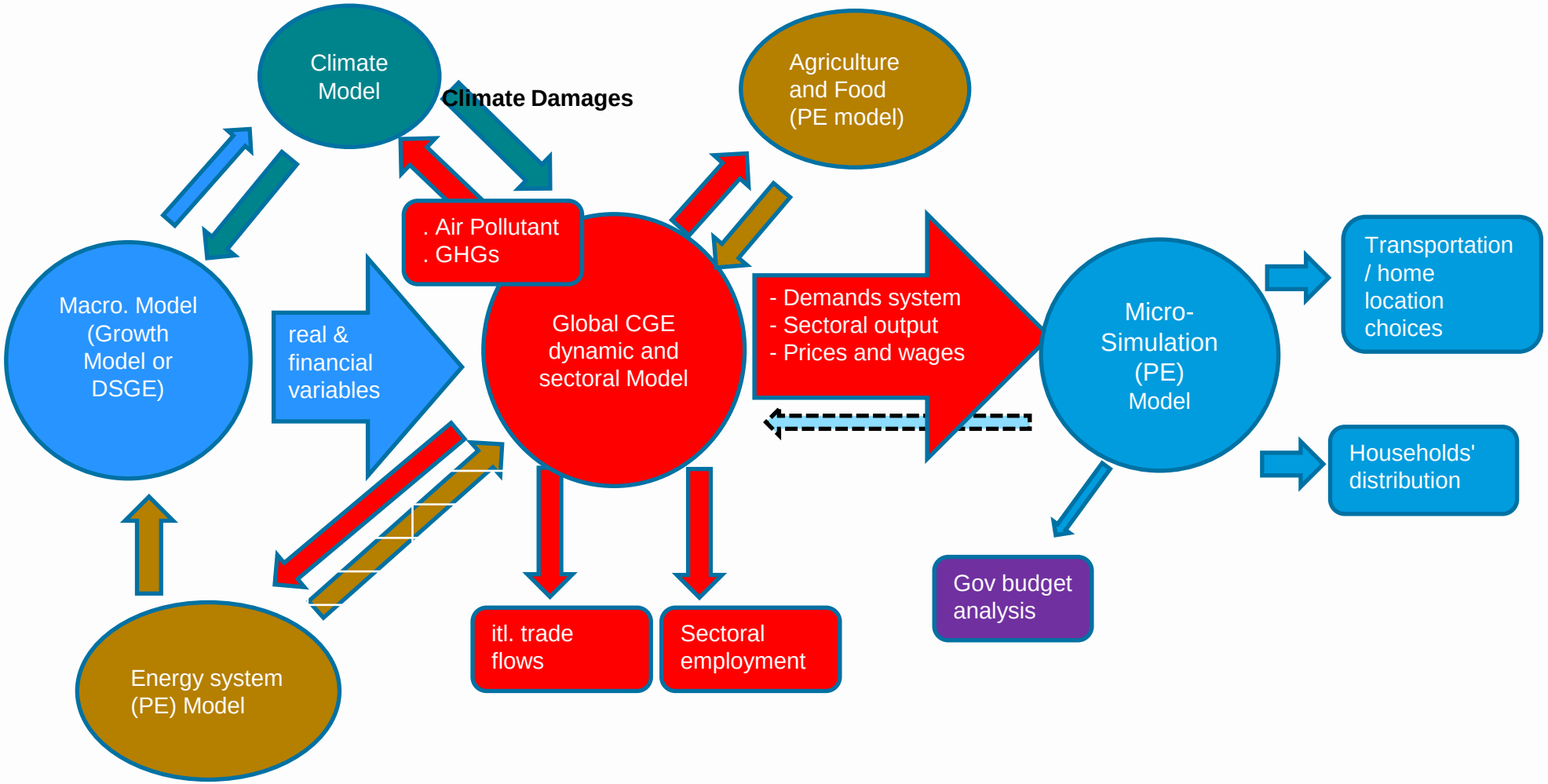
While all this is feasible this strategy raised two issues :

- Is it technically feasible? A standard CGE model with 25 regions and 50 sectors and international trade flows already account for something like 300 000 nonlinear equations for only one year.
- Is it worthy? Do any economic mechanisms and economic relationship need to be endogenous? Probably not. For example, the issue of distributive impacts of C.M.P. is of crucial importance for the political acceptance, but the feedbacks of distribution on the macroeconomic variables are here expected to be small and therefore better to deal with this issue with other tools (World Bank papers)

Option 2: Linking models and tools

- Given complexity of CC analysis, it seems that a more promising way to improve CGE based analysis is to complement these CGE models with other modelling tools.
- There are roughly two ways of linking models soft-linking and hard-linking (Delzeit et al., 2020).
  - The first method consist in passing some information between two models, generally a macro-economic (CGE, IAM,…) & a PE models (for energy system, agriculture). The two models should be harmonized (in terms of baseline, main elasticities), and then information would go from one model into the other, but both model are run separately. This is the easiest solution when the outcome of the PE model will not fundamentally change the overall macro results.
  - The second method consist in running together both models, information pass from one model to the other until the convergence between both model is judged satisfactory.

Example of Models Linking for Climate



Thank You

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