Determinants of GDP responsiveness to regional CO_2 prices in top-down energy-economy models

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The carbon leakage problem

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Introduction

The carbon leakage problem

- Subglobal environmental policy.
  - Some regions (the signatories) adopt environmental constraints to reduce CO_2 emissions.
  - Other regions do not adopt environmental constraints.
- Regional competitiveness.
  - The environmental constraints represent an additional cost incurred only in the signatory regions.
  - Re-balancing the competitive advantages for the benefit of the non-signatory regions.
  - Detrimental effect on activity in the signatory regions.
  - Limited, or even negative on atmospheric CO_2 concentrations (outsourcing of emissions from the signatory to the non-signatory regions).

Two possible definitions of leakage.

- Carbon leakage stricto sensus: measuring the effect on global emissions, beyond the scope of this presentation.
- Carbon-driven economic leakage: measuring the effect on regional wealth: **our topic!**

A major EU concern

- EU ETS Directive (2003/87/EC). Production from sectors deemed to be exposed to a significant risk of carbon leakage will receive relatively more free allowances than other sectors.
- Revision of the directive. A sector or sub-sector is "deemed to be exposed to a significant risk of carbon leakage if:
  - The sum of additional costs induced by the implementation of this directive would lead to a substantial increase of production cost (proportion of the Gross Value Added) of at least 5%; **and** the Non-EU Trade intensity is above 10%."
  - The sum of additional costs induced by the implementation of this directive would lead to a particularly high increase of production cost, of at least 30%; **or** if the Non-EU Trade intensity is above 30%.
- Acknowledgement of the sectorial impact of the EU-ETS. However very optimistic estimation of the overall impact of EU's objectives on climate change and renewable energy for 2020: less than 0.7% change in GDP at horizon 2020.

Assessment of the carbon leakage in top-down dynamic GEM

- A low response of GDP to the carbon policy (as in MERGE, WITCH, REMIND): "The fable of the rabbit and the elephant".
- But these models are based on a very aggregated vision of the economy with no representations of the labor reallocation process among sector accompanying the decrease in CO_2 and energy intensity of the economies.
- They have to rely on equivocal assumptions :
  - Values of the elasticity parameters.
  - Reference scenario.

Objectives and method

- Objectives: assess the influence of elasticity parameters and reference scenarios on the response of the GDP to a unilateral increase in carbon prices.
- Method: compute the magnitude of the response of GDP to the carbon price with a stylized model calibrated on the French economy.
  - Design a multi-sector dynamic general equilibrium model including the factors influencing leakage: GDP composition between energy-intensive and non-energy activities, possibilities of substitutions between energy and non-energy inputs, openness to trade, product differentiation and inter-sectoral labor mobility.
  - Calibrate the model on reference steady-state and non steady-state scenarios of the French economy.
  - Sensitivity analysis: put a counterfactual shock on the carbon price and measure the magnitude of the GDP response for various elasticity parameters and reference scenarios.

The model

A multi-sector Ramsey model of the French economy

- 4 goods: fossil fuels (f), electric energy (e), energy-intensive goods (is) and non-energy intensive goods (ns).
- Basis structure of the economy represented below, in grey the non-zero values.

	Resources		Int. Cons.			Final Use				
								Capital		
	Imported	Domestic	e	is	ns	Cons.	Export	e	is	ns
f	■		■	■	■	■				
e		■		■	■	■				
is	■				■	■	■	■	■	■
ns	■	■		■		■	■	■	■	■

- Armington international trade specification.
- Generic representation of the rest of the world.

$$IM_j^{(s)} = a_{(im),j} PI^{\sigma_j^{(im)}}, \quad EX_j^{(d)} = a_{(ex),j} PD_j^{\sigma^{(exp)}}$$

$IM^{(s)}$ is the rest-of-the-world supply function for goods, it depends on the domestic import price PI. $EX^{(d)}$ is the rest-of-the-world demand function for domestic goods, it depends on the domestic price PD

Vintage representation of production

The total industry-specific intermediate good, capital, and labor demand are noted $X_{i,j,t}$, $K_{i,t}$ and $L_{i,t}$. The total output is noted $Z_{i,t}$. The technologies can be represented as follows:

$$z_{i,t} = \left[\sum_{j \neq i} a_{(prod),i,j,t} x_{i,j,t}^{\frac{\sigma_i^{(prod)}-1}{\sigma_i^{(prod)}}} + a_{(prod),i,L,t} l_{i,t}^{\frac{\sigma_i^{(prod)}-1}{\sigma_i^{(prod)}}} + a_{(prod),i,K,t} k_{i,t}^{\frac{\sigma_i^{(prod)}-1}{\sigma_i^{(prod)}}} \right]^{\frac{\sigma_i^{(prod)}}{\sigma_i^{(prod)}-1}}$$

Dynamics of inputs and outputs:

$$Z_{i,t+1} = Z_{i,t}(1-\delta) + z_{i,t+1}, \qquad X_{i,j,t+1} = X_{i,j,t}(1-\delta) + x_{i,j,t+1}$$
$$K_{i,t+1} = K_{i,t}(1-\delta) + k_{i,t+1}, \qquad L_{i,t+1} = L_{i,t}(1-\delta) + l_{i,t+1}$$

- $\sigma^{(prod)}$: the LT elasticity of substitution, it represents the ability of the sector to face changes in energy prices with little added-value losses.
- $a_{(prod)}$: scaling factors representing exogenous increases of the inputs' productivity.

Limited labor mobility

The total efficient labor LT is exogenous, the quantity of labor lt available at period $t+1$ for the new vintages is:

$$\bar{lt}_{t+1} = \bar{LT}_{t+1} - (1-\delta)\bar{LT}_t \tag{1}$$

Limited labor mobility between the vintages of the various sectors. The representative household is endowed with an exogenous quantity of total labor $\bar{L}_t$, but it chooses the distribution of its labor to the different sectors. To represent the limited labor mobility we follow [Casas 1984] and [Horvath 2000], considering that the household labor supply as an index of the labor supply in the different sectors:

$$\bar{lt}_t = \left[\sum_i a_{(labor),i,t} \, l_{i,t}^{\frac{\sigma^{(labor)}+1}{\sigma^{(labor)}}} \right]^{\frac{\sigma^{(labor)}}{\sigma^{(labor)}+1}}$$

The parameter $\sigma^{(labor)}$ represents the elasticity of substitution between labor from the different sectors. In the limit cases, when $\sigma^{(labor)} = 0$ there is no labor mobility, when $\sigma^{(labor)} = +\infty$ the labor mobility is perfect.

Summary: elasticities and scaling parameters

As the model relies on various functions (some are not mentioned above), it contains several elasticity and scaling factors parameters.

Scaling factors	Elasticities	Location
$a_{(prod),i,j,t}$ $a_{(prod),i,K,t}$ $a_{(prod),i,L,t}$	$\sigma_i^{(prod)}$	**vintage production function**
$a_{(cap),i,is,t}$ $a_{(cap),i,ns,t}$	0	production function for capital goods
$a_{(dom),j,t}$ $a_{(for),j,t}$	$\sigma_j^{(arm)}$	Armington specification
$a_{(im),j,t}$	$\sigma_j^{(im)}$	**foreign supply**
$a_{(ex),j,t}$	$\sigma_j^{(ex)}$	**foreign demand**
β_t $a_{(cons),j,t}$	1 $\sigma^{(cons)}$	inter-temporal utility function static utility function
$a_{(labor),i,t}$	$\sigma^{(labor)}$	**labor mobility function**

The model's results will be largely driven by the values assigned to these parameters: what does the model mean?

Calibration

CGE calibration

A general equilibrium V (commodity prices, activity level...) solves a mathematical problem depending on (i) vectors α and Σ containing respectively the scaling and elasticity parameters and on (ii) a policy-instrument vector τ.

$$H(V, \tau, \alpha, \Sigma) = 0$$

CGE calibration consists in setting a priori a reference scenario $\bar{V}$ for the variables and $\bar{\tau}$ the policy that is **consistent with Walrasian flows**. Then we find α such that:

$$H(\bar{V}, \bar{\tau}, \alpha, \Sigma) = 0$$

The general equilibrium V with the counterfactual policy τ solves:

$$H(V, \tau, \alpha(\bar{V}, \bar{\tau}, \Sigma), \Sigma) = 0$$

Replication checks: the equilibrium reproduces the reference scenario for any Σ

$$H(\bar{V}, \bar{\tau}, \alpha(\bar{V}, \bar{\tau}, \Sigma), \Sigma) = 0$$

Normalized form

Normalization consists in writing this problem on the form:

$$H'(\frac{V}{\bar{V}}, \frac{\tau}{\bar{\tau}}, \bar{V}, \bar{\tau}, \Sigma) = 0 \quad (2)$$

- The model simulates the deviation from a reference scenario resulting from a deviation in the value of the policy instrument, for given (i) elasticity parameters and (ii) reference scenario.
- **In our case**: the deviation of the GDP from the reference GDP resulting from a deviation of the carbon tax, for given (i) elasticities (representing the ability of switching input, goods or labor) and (ii) reference scenario (gains in energy efficiency, deindustrialization...)

Calibration of the reference scenarios

- The reference scenario must be consistent with Walrasian flows in the economy
  Zero profit + Income balance + Market clearance conditions
- Well known in static and inter-temporal recursive CGE modelings: these conditions must be fulfilled by the social accounting data (e.g. the SAM) used to calibrate the model.
- But in dynamic models: the social accounting data is temporal and some of the consistency conditions are inter-temporal.

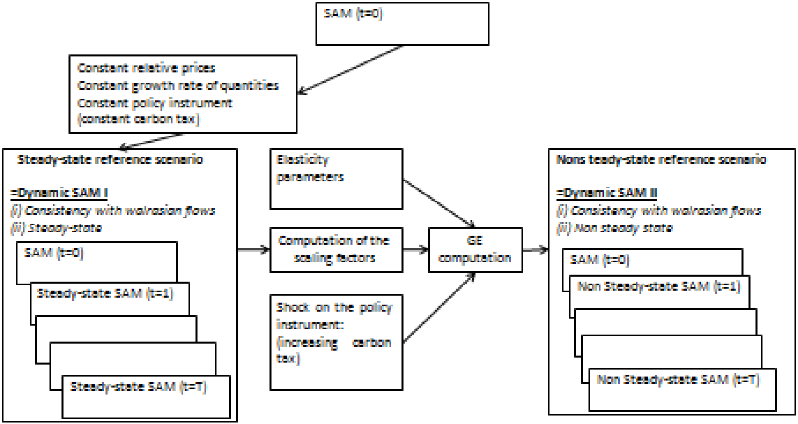
How to project the base-year SAM to obtain an inter-temporal SAM?

- An "easy solution": steady-state calibration, the base-year quantities increase at a constant rate, relative prices are constant.
- But it is relevant as a reference scenario?
    - No change in the structure of the economy: constant breakdown of added value between the industrial sectors, constant energy intensity.

Need for non-steady state reference scenario

- Consistent with Walrasian flow
- Representing a certain pre-defined "vision of the world"

Computation a the non-steady state policy reference scenarios



The policy changes, but technologies and preferences are constant

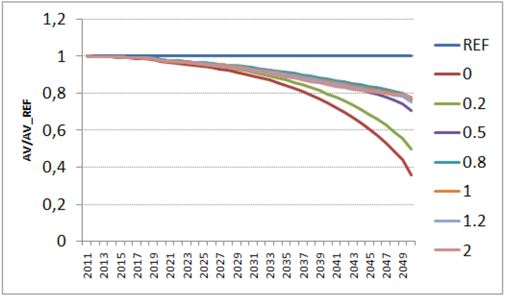
Preliminary Results

Elasticity and reference scenario

- The reference steady-state scenario:
  - Constant growth rate of output: 1.5% per year
  - Constant carbon tax : 15 euros per tCO_2
- The policy shock:
  - We impose a 5% per-year increase of the carbon tax
- The elasticities of substitution in the production sectors of the economy: .2 for *e* and *is*, .7 for *ns*
- In the the non steady-state reference scenario:
  - Economic growth the various industrial sectors lower than 1.5
  - 1% average per year increase in emissions from 2010 to 2050.

Labor mobility and real added-value response in the *is* sector

Response of the added value in the *is* sector to a 100% increase in CO_2 prices from 2020 for various labor mobility parameters.



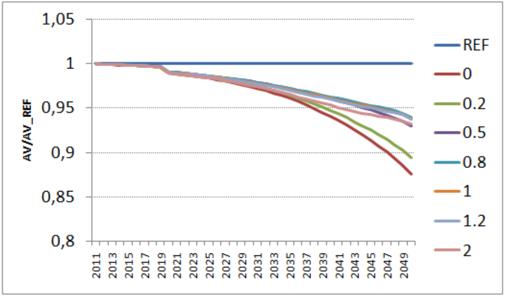
The response in the industrial sector is very important, but it has to be **related to reference scenario and elasticity assumptions**

In particular, in this scenario, the elasticities are low and the technologies remain constant: no autonomous improvement of energy efficiency

Labor mobility can play a significant role in limiting the carbon leakage in the is sector

Labor mobility and real GDP

Response of the GDP to a 100% increase in CO_2 prices from 2020 for various labor mobility parameters. in 2020.



The effect has to be related to the share of *is* sector added value in the reference scenarios.

Conclusion

- A dynamic CGE model, even complex can be solved as a system of deviations from a reference scenario
- The main difficulty consists in formulating reference scenarios that are consistent with both Walrasian flows and a certain vision of the world
- Non-steady state policy scenarios can be generated through counterfactual policy shocks on policy in the general equilibrium model calibrated on a steady state.
- Research direction: toward a better control of the vision of the world in the reference scenario
- Possible solution: changes in technology and preference parameters in the reference scenario through had-hoc choices of elasticities and exogenous shocks on input prices in a model calibrated on a steady state.