A Dynamic Path to a Low Carbon Economy

Cecilia Bellora[♯], Lionel Fontagné [†, ♯, ‡]

[♯]CEPII [†]Banque de France [‡]PSE

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Motivation

Counterfactual approach to assess the impact of trade policies:

scenario *vs* baseline

Policies to mitigate climate change (IPCC + Paris Agreement)

- Transition to low-carbon energies ⇒ structural transformation away from brown industries
- Heterogeneity in the level of commitment of the trade partners:
  - Radical change in the comparative advantages
  - Great risk of leakages (production and GHGs)

⇒ How to take these policies into account in the baseline, even to consider the impact of trade (and not climate) policies?

Motivation (2/2)

Reference path

- Dynamics of GDP of each country
- But *beyond GDP*: demography, productivity, current account, energy efficiency . . .
- . . . sectoral value added, emissions of GHGs

Our approach combines a macroeconomic growth model with a dynamic global and sectoral GE model

What we do

Two models

1. Growth model projects GDP and other relevant variables
2. Dynamic global sectoral GE model
   - Uses these variables as input
   - Combined with MRIO and emissions data
   - Output: sectoral value added, trade, GHG emissions

Two paths for the World economy towards 2040

1. BAU, step 1: ref. path of the world economy, *no climate policy*
2. BAU, step 2: Step 1 + COP26 unconditional NDCs (EU27: Fit for 55 package, as presented in July 2021)

Literature

- Dynamic baselines
  - Construction (Chappuis and Walmsley, 2011; Fouré et al., 2020)
  - Scenarios (Dellink et al., 2017; Fontagné et al., 2017)
- Climate policies
  - Implementation cost of Paris under different CO_2 trading schemes (Böhringer et al., 2021a)
  - With different kind of models (Böhringer et al., 2021b)
  - CBA (Babiker and Rutherford, 2005; Cezar and Grieco, 2021), CCBA (Weitzel et al., 2012; Antimiani et al., 2013; Manders and Veenendaal, 2008)
  - Compensatory tariffs (Böhringer et al., 2012, 2021b)
- Integrated Assessment models
  - Surveyed in Weyant (2017)

Tools

MaGE

- Macro trajectory with 2040 horizon
- Demographics, female labor market participation, education, technological catch-up, energy efficiency, lifecycle, current account

Dynamic General Equilibrium ▸ MIRAGE-VA

- Macro baseline – MaGE
- Global & multi-sector – Database GTAP 10.1
- Implicit techn. progr. – substit. K$\sim$E and non-CO_2 $\sim$ conventional inputs
- GVCs: GTAP MRIO
- Imperfect competition
- GHGs (carbon dioxyde, methane, nitrous oxide, fluor. gases) ▸ Nesting
- Energy productivity ▸ Derivation

3-steps procedure

1. 1st step: 2040 horizon projected by MaGE in MIRAGE
   MaGE+MIRAGE

2. 2nd step: Brexit in MIRAGE (and other trade policies of the BAU)

3. 3rd step: unconditional NDCs (COP26) + Fit for 55 in MIRAGE Paris Ag. & Fit for 55

   - EU ETS
   - EU Carbon tax on non-ETS sectors (= taxes + implicit cost of regulations)
   - EU: CBAM & phase out of FAs
   - Other countries with unconditional NDCs + nat. wide carbon price: one level of carbon tax

$\Rightarrow$ What does the third step change?

BAU I: A world with no climate policy (1/2)

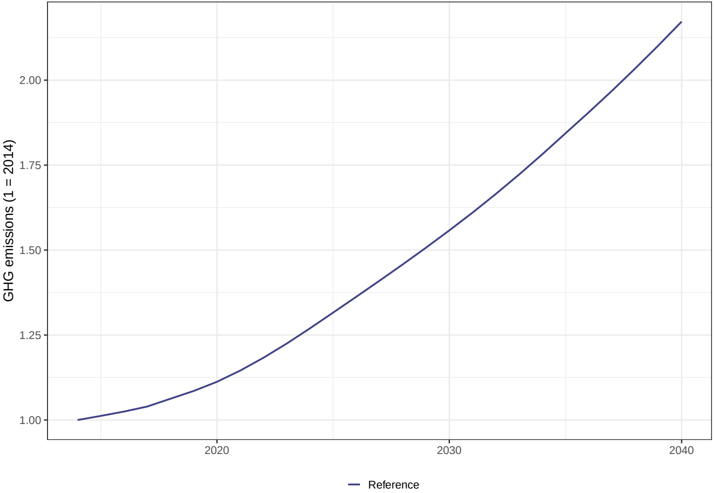
Table: Share of each region on World totals

Region	GDP		Exports		Emissions	
	2014	2040	2014	2040	2014	2040
United States	21.9	15.7	9.5	7.8	14.8	10.5
European Union 27	20.1	12.0	30.1	21.2	8.9	4.8
China	13.3	26.7	12.0	17.2	23.3	31.4
(...)						
India	2.6	8.3	2.0	8.5	7.2	16.6

Notes: Countries are ranked by decreasing contribution to the World GDP in 2014. The 4 top emitting countries in 2014 and 2040 are shown.
Source: MIRAGE-VA, calculations by the authors.

BAU I: A world with no climate policy (2/2)

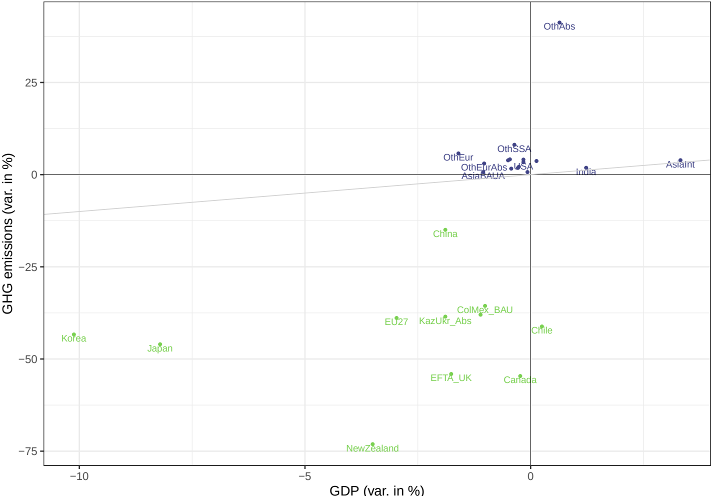
Figure: World emissions of GHGs in the BAU



Source: simulations with MIRAGE-VA, calculations by the authors

BAU II: A world with a non-cooperative climate policy (1/4)

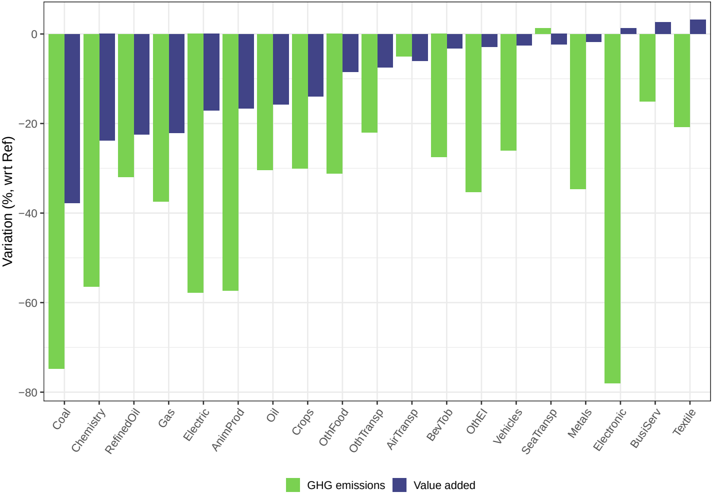
Figure: Impact on GDP and GHG emissions: percentage change wrt the BAU I in 2040



Source: simulations with MIRAGE-VA, calculations by the authors

BAU II: A world with a non-cooperative climate policy (2/4)

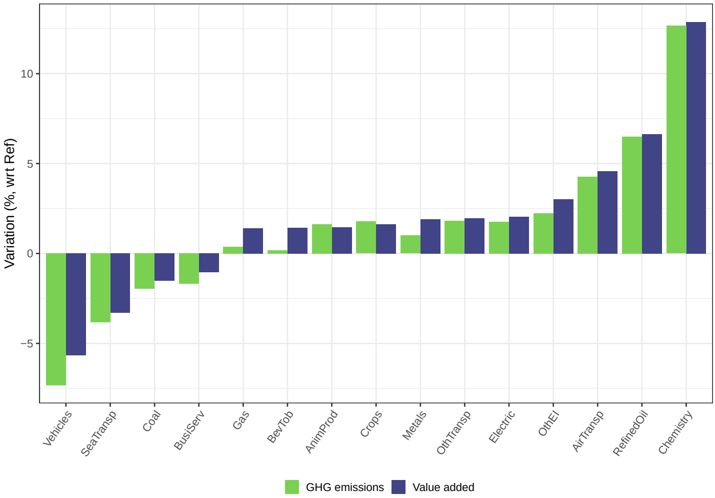
Figure: EU27 – Impact on VA by sector and GHG emissions, percentage change wrt the BAU I in 2040



Source: simulations with MIRAGE-VA, calculations by the authors

BAU II: A world with a non-cooperative climate policy (3/4)

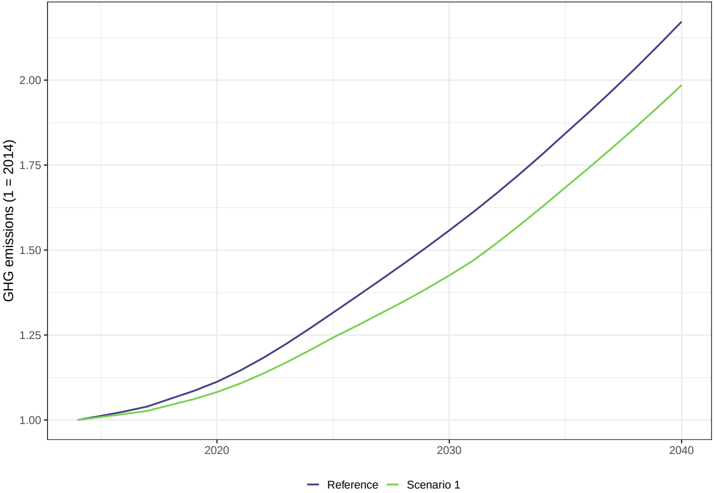
Figure: India – Impact on VA by sector and GHG emissions, percentage change wrt the BAU I in 2040



Source: simulations with MIRAGE-VA, calculations by the authors

BAU II: A world with a non-cooperative climate policy (4/4)

Figure: World emissions of GHGs in the BAU I and in BAU II



Source: simulations with MIRAGE-VA, calculations by the authors

Conclusions

1. Mitigation policies results in a large structural change that possibly influences the outcome of trade policies
2. Countries involved in mitigating their emissions bear a high cost in terms of GDP because of leakage
3. Non-participating countries hardly benefit from leakage because demand in participating countries collapses

Thank you

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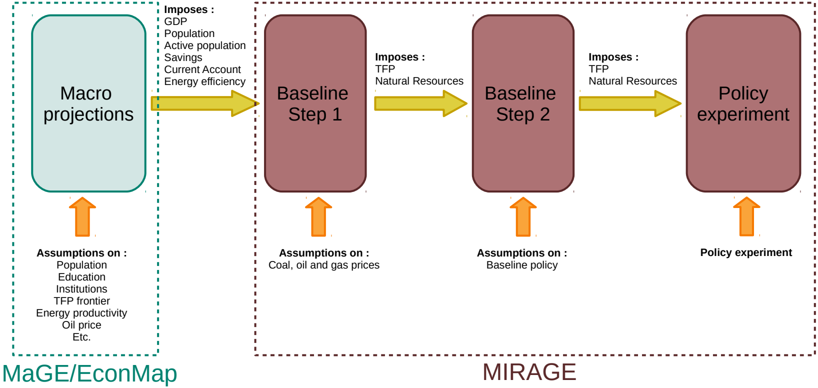
Plugging MaGE & MIRAGE



▸ Back

MIRAGE-VA in detail

1. Multi-region, multi-sector, recursive dynamics;
2. Production
   - Imperfect competition (mark up): manuf & services
   - Perfect competition (representative firm): agriculture
   - Production combines:
     - Factors: unskilled, skilled, capital, land, nat. res., energy
     - Intermediate consumptions
3. Demand
   - Representative household, LES-CES preferences
   - Trade: Armington assumption
   - Distinction trade in intermediate *vs* final goods
4. Environment
   - CO_2 emissions proportional to fossil energy consumption
   - Other GHGs (Nitrous oxide, methane and fluorinated gases) emitted during the production process (Hyman et al., 2003)

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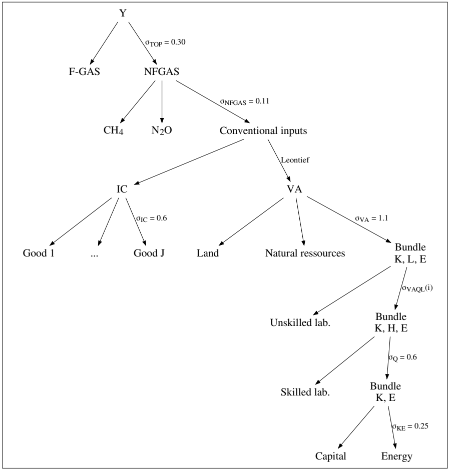
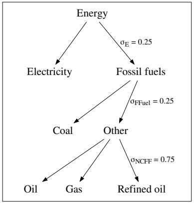
MIRAGE-VA nesting

Figure: Production structure – Industry (not ETS nor services)





cf. EPPA Model - Emission Prediction and Pol. Analysis (Hyman et al., 2003)

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Energy efficiency – From MaGE to MIRAGE

In MIRAGE-e, for sectors other than those of fossil energies (coal, gas, refined oil and crude oil) :

$$E_{irt} = \alpha_E \frac{\tilde{B}_{irt}}{[A_{irt}]^{\sigma_{KE}-1}} KE_{irt} \left(\frac{P_{irt}^{KE}}{P_{irt}^{E}} \right)^{\sigma_{KE}}$$

with $\tilde{B}_{irt}$:

- equal to 1 for the calibration and the reference year,
- in the simulations, it follows the dynamic path given by $\left[\tilde{B}_{irt} = \tilde{B}_{ir,t-1} \frac{B_{rt}}{B_{r,t-\mathbf{1}}}^{\sigma_{KE}-1} \right]$ with B the energy productivity projected by MaGE

and A_{irt}: 3 different TFP paths, according to the sector (i)

- Services: Mage projected path
- Industry: growth rate more rapid than in the services, +2 p.p. per year
- Agriculture: specific estimation and projection (DEA)

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MaGE in detail

Production function with 3 factors and 2 TFPs (van der Werf, Energy Econ., '08)

$$\max\left(Y - p_K K - p_L L - p_E E\right) \tag{1}$$

s.t.

$$Y = \left[\left(AK^{\alpha}L^{1-\alpha}\right)^{\frac{\sigma-1}{\sigma}} + (BE)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

Energy demand from FOCs:

$$E = Y\frac{B^{\sigma-1}}{p_E^{\sigma}} \tag{3}$$

After substitution, the projected GDP is given by

$$Y = \left[1 - \frac{B}{p_E}\right]^{\frac{\sigma}{1-\sigma}} AK^{\alpha}L^{1-\alpha} \tag{4}$$

$\alpha = 0.31$ (Mankiw, Romer & Weil, 1992)

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Implementation of the Paris Ag. & Fit for 55 in MIRAGE (1/3)

- Only unconditional commitments are taken into account (Absolute, BAU, intensity) $\Rightarrow$ GHG target, in Mt CO_2 eq
- Only in countries with a nation-wide carbon price in place by 2021 (ARG, CAN, CHL, COL, ISL, JPN, KAZ, KOR, MEX, MNE, NZL, NOR, SGP, CHE, GBR, UKR)
- Specific treatment of China's pledges
- Linear reduction of emissions between 2014 and the NDC's target year
- The price of GHG emissions (i.e. the carbon tax) is computed endogenously to reach the target

Implementation of the Paris Ag. & Fit for 55 in MIRAGE (2/3)

- 3 types of unconditional NDCs :
  - Absolute: target in tons of CO_2 eq;
  - BAU: reduction in relative terms wrt a reference situation established by the country itself;
  - Intensity: target in tons of CO_2 eq per dollar of GDP.
- What we impose in the model: total GHG emissions, by carbon market/region and by year.
- How are the 3 types of NDCs represented in the model?
  - Absolute: linear decrease btw the initial year and the target year to reach the targeted emissions ;
  - BAU: translated in an absolute target ;
  - Intensity: total GHG emissions endogenously computed based on the GDP in the simulations, given the targeted intensity.

Implementation of the Paris Ag. & Fit for 55 in MIRAGE (3/3)

The EU27 implements the commitment taken in the Paris Ag. (-55% in 2030 wrt 1990) based on the approach proposed in the *Fit for 55* package, in July 2021:

- Specific target for ETS: -61% in 2030 wrt 2005
- Carbon Border Adjustment Mechanism complements the ETS:
  - Progressively replaces free allowances (phased out btw 2026 and 2035);
  - Based on the direct emissions of the exporter;
  - Allowances purchased by the importers on a market distinct from the ETS, price-taker wrt the ETS;
  - Covers all the goods already covered by the ETS;
  - Revenues to the EU27 general budget;
  - Cf. Bellora and Fontagné (2022)

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