Development of the IMACLIM-S Brazil model

William Wills

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Summary

1. Introduction

2. Hybrid modeling for a new perspective
   i. Previous studies on Brazilian mitigation options
   ii. CGE Hybrid models potential

3. IMACLIM: General Framework

4. Technical Content
   i. Data processing: how to build “hybrid” accounts
   ii. BAU projection for Brazil in 2030
   iii. Carbon constraint derived equilibrium
   iv. How to integrate expert-based information on mitigation options

5. Preliminary results with 3 sectors

6. Perspectives
Introduction

• Brazil’s voluntary GHG emission mitigation goals until 2020
• Impacts of the voluntary goals in the economy
  – Total GDP cost?
  – Impacts on labor market?
  – What cost-efficient policy package for what overall public policy objectives?
  – Follow-up: Which policies should be applied after 2020?
• IMACLIM-S hybrid framework
  – Brazil as an opened economy
  – A dialogue structure to capture interactions between “bottom-up” sectoral information, overall technical change and macroeconomic parameters
  – Assess welfare and economic medium and long term consequences of climate policies
Previous studies on Brazilian mitigation options

• **PNE 2030**
  – Provides information on GHG emissions and some mitigation options (energy efficiency)
  – No CGE model to assess macroeconomic consequences

• **McKinsey**
  – Considers the main economic sectors and evaluates more than 120 mitigation measures
  – No technical model and no CGE model to secure technical and economic consistency

• **Low Carbon Study (World Bank)**
  – Wide bottom-up analysis of mitigation actions in the main sectors
    • Expert-based abatement curves (MAC curves) were built
  – Microeconomic cost-benefit analysis for 40 mitigation options
    • Options below 50US$/ton reduces GHG emissions in 40%.
  – An input-output (I-O) framework
    • Limited by its lack of constraints on supply of goods and labor
    • The study suggested the use of a CGE model to conduct this kind of assessment

• **Economia do Clima no Brasil**
  – Different point of view. Estimates the costs related to Climate Change in Brazil.
  – Carbon Tax: A CGE model estimated a 1.8% GHG emissions reduction per year with a 50US$ carbon tax. In this scenario the GDP would be reduced in 0.13% per year.
    • Fixed emissions coefficients (level of emissions/level of activity) (Pg 304).

What is a model with the capacity to embark expert-based abatement curves in a CGE framework
IMAACLIM-S framework

• Description of the carbon constrained GE future of the economy
  – « hybridized » description of economic flows both in physical quantities and money value
  – Multiples markets
  – Four sectors: Households, companies, state and rest of the world

• **BUT** producers and consumers behaviors calibrated on expert-based information (technology, etc.) :
  – Simulate large departures from base year compared to BAU scenario without the limitations of conventional production functions
  – physical asymptotes, induced technical progress, material and spatial constraints (land-use)

• Prerequisite: build an « hybridized » social accounting matrix
“A change in the relative prices of the factors of production is itself a spur to invention and to inventions of a particular kind—directed at economizing the use of a factor which has become relatively expensive” (Hicks, 1932, p. 124).
The meaning of a comparative statics framework (Samuelson)

- Comparison between one BAU projected equilibrium and carbon constrained derived equilibriums respective to a time horizon
- Policy-equilibrium is completed a) after behavior and market adjustments b) considering *innovative possibility curves* generated at a given time horizon
Hybridation Methodology

• Consists in describing economic flows both in physical quantities and monetary values.

• Enables to build models that guarantee that any projected economy is supported by relevant “physical system” and conversely that technological deployment appears in realistic economic environment.

• It helps not only to calibrate the model, but also to have a consistent picture of the economy
Hybridation Methodology: Data

• The national accounting matrix (IBGE, 2005)
  • 110 products, 55 sectors
  • Needed careful manipulation to transform it into an \((n \times n)\) input-output matrix (I/O)
  • I/O matrix: columns are the cost share structures, rows give the ‘sales’ structure 2005.

• National Energy Balance (EPE)
  • Also need to transform it into an input-output table consistent with the input-output matrix in values.
# Input-Output Matrix

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<th>CI</th>
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<th>Oil-Gaz</th>
<th>ET</th>
<th>Elec</th>
<th>Cost</th>
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<th>Pap</th>
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<th>Steel</th>
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**Total Transformação: 30.665**
Hybridation Methodology: basic principle

- Securing the consistency between prices, physical quantities and economic flows

\[ V = P \cdot Q \]
Hybridation Process: bridging the nomenclature gaps

ex: refining products all together in IBGE column, including the non energy products

1- Ajustement des Emplois
Valeurs non liées aux flux de matière affectés au composite ($V'_{ij}$)

Factures des achats de matière

2- Ajustement des ressources
(a) Désagrégation des structures de coûts et taux de marge
(b) Valeurs non liées aux flux de matière affectés au composite

Factures des achats de matière

Sources statistiques disponibles

Étape 1

Matrice en volume (unité physique)

CI | CF
---|---
MAT | $Q_{ij}$

Matrice en prix (monnaie/unité physique)

CI | CF
---|---
MAT | $P_{ij}$

Étape 2

Factures des achats de matière

CI | CF
---|---
MAT | $V_{ij} = P_{ij} \cdot Q_{ij}$

Étape 3

Ajustement des Emplois
Valeurs non liées aux flux de matière affectés au composite ($V'_{ij}$)

Factures des achats de matière

2b

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ex: refining products all together in IBGE column, including the non energy products
Hybridation Process: the disaggregation level

- Final matrix: 18 sectors
  - 6 energy sectors (ktoe)
    - Coal
    - Oil
    - Natural Gas
    - Refined products
    - Electricity
    - Biomass
  - 6 industrial sectors (ktons)
    - Paper
    - Cement
    - Steel
    - Non Ferrous
    - Mining
    - Chemical
  - 6 other sectors
    - Agriculture
    - Livestock
    - Construction
    - Transport
    - Rest of industry
    - Composite
## Input-Output matrix after Hybridation

| CI | CF | Total 
|---|---|---
| **Coal** | | 
| 12 | | 3012 | 192 | 291 | 3953 |
| 0 | | 0 | 0 | 0 | 0 |
| **Cr** | | 
| 0 | | 6487 | 16 | 196 | 1012 | 10017 |
| **Gaz** | | 
| 0 | | 0 | 0 | 0 | 0 |
| **ET** | | 
| 0 | | 202 | 354 | 10367 | 384 | 3564 | 375 |
| **Elec** | | 
| 32 | | 0 | 0 | 0 | 0 |
| **Cont** | | 
| 0 | | 139 | 30 | 3796 | 144 | 129 | 948 |
| **Transp** | | 
| 0 | | 0 | 0 | 0 | 0 |
| **Agri** | | 
| 0 | | 807 | 118 | 19678 | 4310 | 278 | 2498 | 1044 | 31 |
| **Pop** | | 
| 5 | | 79 | 109 | 6661 | 36 | 221 | 18 | 32 | 12350 | 784 | 726 | 645 |
| **Cem** | | 
| 0 | | 46 | 0 | 55 | 0 | 1 | 1 | 1594 | 47 | 621 | 0 |
| **Steel** | | 
| 2 | | 18 | 0 | 4944 | 0 | 157 | 14 | 156 | 10384 | 878 | 44273 | 67 |
| **NF** | | 
| 0 | | 24 | 176 | 766 | 21 | 4 | 4 | 2191 | 2210 | 12901 | 177 | 3076 | 0 |
| **Indus** | | 
| 17 | | 80 | 1295 | 408 | 2312 | 5413 | 778 | 1126 | 2169 | 7369 | 342722 | 13695 |
| **Com** | | 
| 29 | | 14116 | 5935 | 17433 | 5479 | 33263 | 1955 | 3183 | 6309 | 380303 | 622111 | 417805 | 5813 | 33945 | 138562 |

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<td><strong>Outros subsídios e produseio</strong></td>
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## Total Ressources

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## Equilibre Emploi-ressources

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Our project: regulatory aspects of a carbon market on heavy industry, energy and land-use change at time horizon 2030.

Land-use change is not included in a 1st step (will be included after sensitivity tests and stabilization of the model).

Aggregation: 12 sectors

- 5 energy sectors: biomass, crude oil, natural gas, refined oil and coal products
- 6 industry sectors: paper, cement, steel, non-ferrous products, chemicals and minerals
- Residual Composite Good
General structure

- **Price structure:**
  \[ pY = \sum \alpha \cdot pCI + w \cdot l + pk \cdot k + \pi \cdot pY + \tau \cdot pY \]
  \[ p = \frac{pM \cdot M + pY \cdot Y}{M + Y} \]

- **Equilibrium on market goods:**
  → insure « hybrid » equilibrium
  \[ Y + M = \sum \alpha \cdot Y + C + G + I + X \]

- 4 sectors: households, production sectors, public administration and rest of the world

At base year accounts are calibrated on *Contas economicas integradas* (IBGE)
A BAU projection for Brazil in 2030

- Mainly based on scenario B1 of PNE 2030
- Energy balance from 2030 transformed in I-O framework

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<th>Bio</th>
<th>Coal</th>
<th>Oil</th>
<th>NG</th>
<th>Refined oil products and ethanol</th>
<th>Elec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rate of real growth</td>
<td>3,4%</td>
<td>5,7%</td>
<td>2,4%</td>
<td>6,3%</td>
<td>3,4%</td>
<td>4,5%</td>
</tr>
<tr>
<td>Multiplier between 2005 and 2030 domestic production</td>
<td>2,32</td>
<td>4,04</td>
<td>1,82</td>
<td>4,59</td>
<td>2,29</td>
<td>2,99</td>
</tr>
</tbody>
</table>

- Hypothesis of real growth for others sectors driving final consumption

<table>
<thead>
<tr>
<th>Energy sources</th>
<th>Agriculture</th>
<th>Industry</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rate of real growth</td>
<td>4,3%</td>
<td>3,7%</td>
<td>4,3%</td>
</tr>
<tr>
<td>Multiplier between 2005 and 2030 domestic production</td>
<td>2,83</td>
<td>2,46</td>
<td>2,83</td>
</tr>
</tbody>
</table>
BAU projection: some important parameter assumptions

- Historical trend for non-energy technical coefficients + adjustments of imports to reach the balance: I-O matrix in quantities
- Global structural change towards services and better lower energy intensity of the GDP
- IBGE projection of population and active population gives labor productivity assuming a constant unemployment rate (around 7.5%)
- Institutional sectors accounts:
  - Constant tax and transfers rates
  - Explicit debt dynamic
    - Debt equation
    - Constant share of public debt in GDP (from PNE): 33.9%

\[
D = D_0 - \Delta t \times CAF_0 - \frac{\Delta t}{2} (CAF - CAF_0)
\]
Carbon constrained equilibrium calculation

- The carbon price is a « shock » which displaces BAU-equilibrium:

- New equilibrium results are located along innovation possibility curves generated by the accumulation of economic signals over the period

- Households and final consumption:
  - Constant savings
  - Demand function: constant shares of total expensed income for each good

- Production sectors and trades-off in production
  - Energy and industry: substitution possibilities between energy and capital and between energy sources
  - Rest of the sectors: Leontieff functions

- Federal state: public expenses follow GDP variations
From expert-based data to innovation possibility curves

• Data from LCS: discrete mitigation options to be possibly implemented over a 20 years long period (from 2010 to 2030) characterized by an average carbon price, capital costs and variations of energy consumption structure

• Hypothesis: embed all possible technical change in industry and energy at time horizon 2030

• 3 sections in the MACCs:
  – Low carbon prices: efficiency gains
  – Medium carbon prices: substitution between fossil fuels and renewable biomass
  – High carbon prices: substitution between others fossil fuel and natural gas
Innovation possibility curves for efficiency gains

- Substitution possibilities between energy and capital
- Hybrid model structure:
  \[ \alpha_{energy} = f \left( \frac{pE}{pK} \right) \]
- From the MACC to the (E/O ; Pe/Pk)
  - Trades-off independent from output levels
  - cumulative options
- Interpolation with arctangent function with asymptotes
Innovation possibility curves for efficiency gains
Preliminary results with 3 sectors

• Aggregated level with three sectors:
  – Energy sector (crude oil, biomass, natural gas, coal, refined oil and electricity)
  – Industry sector (including the sectors of heavy industry previously detailed)
  – Composite sector (agriculture, construction, transports, rest of industry and services)

• Carbon tax is charged on energy and industry sectors but not on composite sector and final consumption.
Preliminary results with 3 sectors: why the overall public policy objectives matter

Two set of runs:

• Set 1: runs with a fixed carbon tax of 200 reais per ton with 4 different carbon revenues distribution options:
  – option 0: carbon revenues used to decrease public debt
  – option 1: carbon revenues are used to decrease payroll taxes under the constraint of budget neutrality
  – option 2: carbon revenues are used to decrease payroll taxes under the constraint of a constant total public tax income relative to GDP
  – option 3: carbon revenues are used to decrease payroll taxes under the constraint of a constant public debt relative to GDP

• Set 2: under option 1, we run a range of carbon price between 0 to 500 reais per ton in order to estimate a MACC for the sector industry and compare it to the “static” MACC.
Preliminary results with 3 sectors

**GDP Growth**

- **Total**
- **Energy**
- **Industry**
- **Composite**

**Output Growth**

**Production Price Growth**

- **Energy**
- **Industry**
- **Composite**
Preliminary results with 3 sectors

Debt Growth

- Household
- Private sector
- Government

Number of jobs (million)

Unemployment rate

Emissions Growth

Holseholds
Private sector
Government

Debt Growth

Holseholds
Private sector
Government

Number of jobs (million)

Unemployment rate

Emissions Growth

Holseholds
Private sector
Government

Debt Growth

Holseholds
Private sector
Government

Number of jobs (million)

Unemployment rate

Emissions Growth

Holseholds
Private sector
Government

Number of jobs (million)

Unemployment rate

Emissions Growth

Holseholds
Private sector
Government

Number of jobs (million)

Unemployment rate

Emissions Growth

Holseholds
Private sector
Government
Expert-based MACC X IMACLIM MACC

![Graph showing expert-based MACC and IMACLIM MACC comparisons.](image-url)
Next steps

• Scenario on MESSAGE reproducing the PNE 2030 scenario for the electricity sector – Baseline
  – Linkage between the two models will provide consistent prices and demands.

• Linkage to a LUM provided by IPEA

• In the future: long-term scenario (2050)
Thanks!

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