C.I.R.E.D.
Centre International de Recherche sur l'Environnement et le Développement

Models to support discussion on the climate/development nexus

The IMACLIM experience

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Presentation outline

- Methodology
  - The economy-wide dimension of the energy transition modelling challenge at a glance
  - IMACLIM: A hybrid top-down/bottom-up modelling architecture
  - …Operating in 'second-best' transitional setting
  - …Covering distributional issues
- Applied analysis
  - Brazil: oil exploration in a low-carbon development context
  - South Africa: technical rigidities/carbon tax recycling into education
  - Saudi Arabia: macroeconomics of oil price variations

Methodology

The economy-wide dimension of the low-carbon transition modelling challenge at a glance

- Energy transitions are an investment challenge: they can crowd out other investment and raise the risk of stranded assets
- They change costs of E services, which prompts structural change of economic activity via Input-Output relationships under inertia of consumption and production structures
- They are framed by direct & indirect, price & non-price public policies
- Distributional impacts affect aggregate savings and investment behaviour
- Exchange rate adjustments compensate trade balance impacts and retroact on domestic purchasing power—or do not
- Economy-wide impacts feed back on energy mix, energy costs and merit order of technological options

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In total,

What aggregate impact on

growth, unemployment,

income inequality?

IMACLIM
A hybrid TD/BU modelling architecture

- 'Top-down' (TD) economy-wide analysis
  - Input-output accounts of comprehensive economic flows interactions inc. international trade, disaggregated in 2 to 20+ sectors depending on focus
- Coupled to 'bottom-up' (BU) modelling of energy systems
  - Because standard optimisation functions of households' and firms' choices ill-adapted to complex aggregate adjustments of inert, discrete systems
  - Soft coupling with local-partner BU models via iteration of linking-variables exchange, to convergence
- Based on reconciled energy balance and national accounts data
  - Matrices of energy expenses & flows linked by explicit consumer-price matrix
  - Modelling of agent-specific prices beyond tax differentiation

…That accounts for transition dynamics rather than model long-term equilibria

- Imperfect factor mobility and input substitution
  - Labour segmented in skill levels hampers sectoral mobility
  - Investment flow, not K stock, mobile and technologically flexible
  - Technical asymptotes constrain conventional substitution, when used
- Regulated markets
  - Equilibrium unemployment to account for L regulations/market imperfections
  - Agent-specific prices allow modelling administered prices
  - Real exchange rate variations reflect fixed nominal rate if required
- 'Second best' economic setting if only for distorting tax systems
  - 1st best options not necessarily... 1st best (Lipsey and Lancaster, 1956)

…In a framework that captures income distribution issues

- IO framework extended to Social Accounting Matrix
  - Income of primary factors including natural resource rent properly distributed across households, firms, public administrations—public involvement issues
  - Secondary distribution via transfers including direct taxes, social transfers and interest payments on net debt positions tracked as accumulated deficits
- Transition policies mix of market incentives and regulations that affect public income via structural change and relative price shifts
- Distribution across agents of aggregate gains or losses hangs on public budget closure assumption: adjusting taxes vs expenses vs public debt

…to capture distributional impacts and shifts of aggregate Investment and Savings behavior

Applied analysis
3 illustrations

IMACLIM-Brazil
A co-development with COPPE-UFRJ

- Base year 2005, SAM from IBGE, E balance from EPE – ministry of energy
- 12 sectors, 6 E: bioenergy, coal, oil, natural gas, refined oil, electricity; 6 non-E: freight transportation, passenger transportation, livestock, agroindustry, industry, composite
- Coupled to MATRIZ or BLUM models at COPPE
- Transport and fuel demand modelling: private transport bundle with LDVs in utility function; substitution between gasoline and ethanol to reflect the specifics of the Brazilian LDV fleet (‘flex fuel’)
- Oil sector modelling: exogenous output, endogenous domestic demand defines export capacity

Brazil 2030
Low-carbon development and oil exploration

- 2°C-compatible Deep Decarbonisation scenario has low GDP cost … thanks to oil exports that leak CO2 emissions and hamper economic diversification

	GOVernmental NDC scenario	OIL-intensive scenario	Deep Decarb. scenario
Real GDP deviation (% GOV)	-	+0.44	-0.14
Real exch. rate dev. (% GOV)	-	-1.5	+3.0
Real Hh income dev. (% GOV)	-	+0.3	+0.9
Industry exports dev. (% GOV)	-	+0.8	-1.8
Industry output dev. (% GOV)	-	+0.9	-1.5
Oil exports revenue (% GDP)	2.7	2.5	3.0

Source: Lefèvre, Wills and Hourcade, 2018, *Climate Policy*

IMACLIM-South Africa
With academic support from ERC-CTU

- Base year 2005, SAM from StatsSA, energy data from RSA, ERC, IEA
- 10 Sectors, 5E: coal, oil, natural gas, refined oil, electricity;
  5 non-E: energy-intensive industries, manufacturing, transport services, low-skill sector, high-skill services
- Partial hybridisation with South Africa TIMES model (SATIM) of ERC on technical coefficients of electricity sector
- Labour disaggregated in 3 segmented, imperfect, skill markets
- 5 household classes

Financial support from
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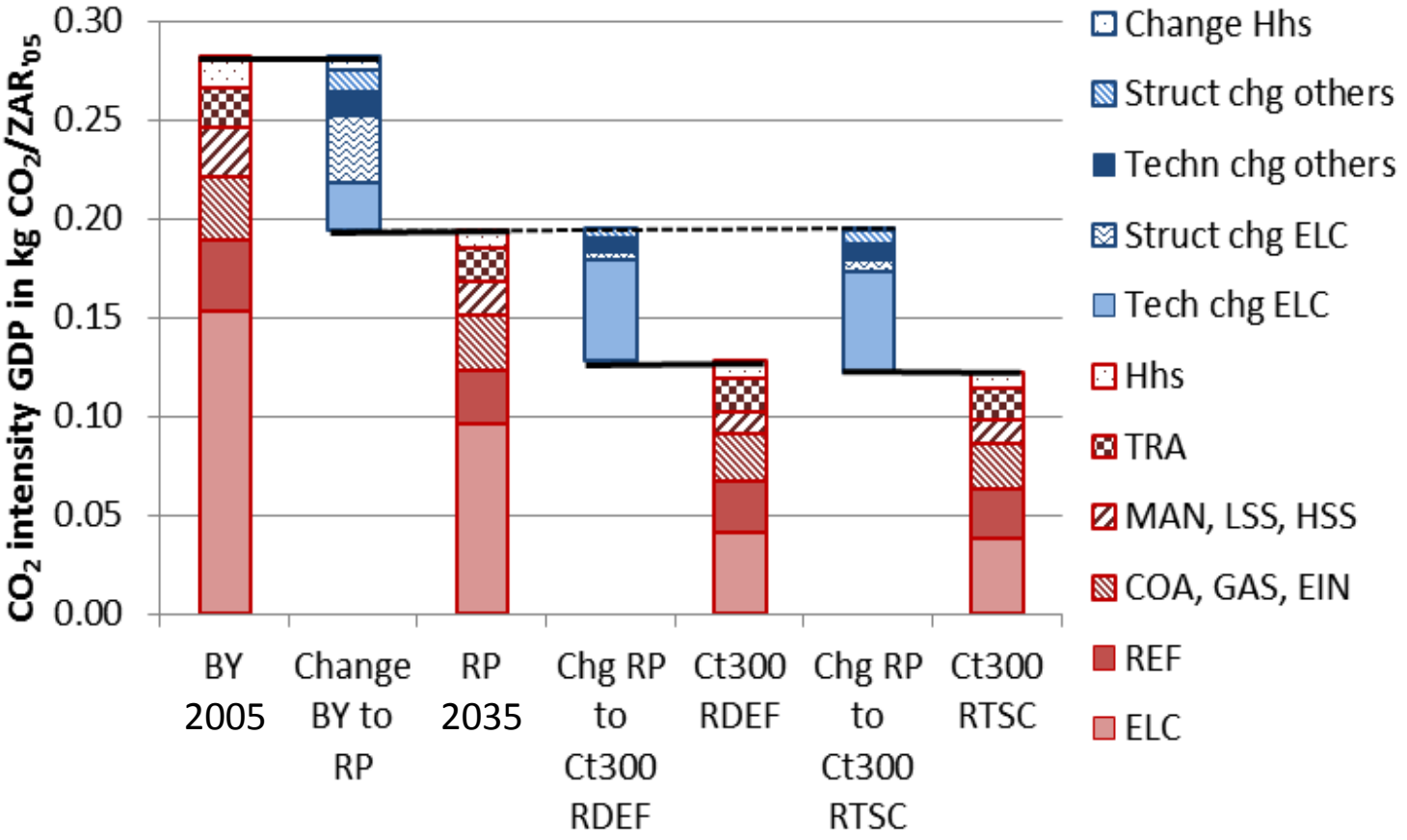
South-Africa 2035
Mitigation potential mostly in power generation



Source: Schers, J., PhD thesis, CIRED

South-Africa 2035
Closing the 'skills gap' favours activity… and CO_2

- 2035 impact of yearly diverting ZAR7.5B of carbon tax proceeds (ca 10% of ZAR100 carbon tax income) to allow 750k additional high-skill actives in 2035 (+11%)
- For 3 carbon tax scenarios with different recycling options

Scenario	2035 GDP	2035 *u*	2035 CO_2	2035 CO_2/GDP	Income gap*
ZAR100 C tax funding L subsidies	+5.7%	-2.2 pts	+4.6%	-1.0%	-2.2%
ZAR300 C tax funding L subsidies	+4.3%	-1.4 pts	+3.5%	-0.8%	-2.4%
ZAR100 C tax funding sales tax cuts	+5.1%	-2.2 pts	+4.5%	-1.0%	-2.2%

**Income gap measured as ratio of household-class-5 income to class-1 income*

Source: Schers, J., PhD thesis, CIRED

IMACLIM-Saudi Arabia
With academic support from KAPSARC

- Base year 2010, SAM from SAMA, energy data from SAMA, IEA, ARAMCO…
- Compact 2-sector 'KLEM' aggregation to tackle macroeconomics of currency peg: 3.75 Saudi Riyals to 1 USD since 1986 ⇨ hard link between trade balance contribution to GDP and real effective exchange rate
- (13-sector version at trial stage ⇨ diversification issues)
- Hybridisation with Kapsarc Energy Model (KEM), one-way so far
- Planned disaggregation of labour in high/low skill and national/foreign

Financial support from
Electricité de France *(EDF)*

Saudi Arabia 2032
Global mitigation & cumulated foreign assets

- 2032 impact of IEA World Energy Outlook 2016 scenarios changing oil price only: +14% in CPS, -28% in 450S compared to NPS baseline---constant oil exports
- Maintaining investment share reduces GDP loss but at the cost of much-reduced domestic savings---what share of decrease supported by public budgets?

Scenario	2032 GDP 2011 = 1	2032 u rate 2011 = 5.4%	2032 REER 2011 = 1	2032 B/GDP 2011 = 29.3%	CFA* Bn 2011 USD
NPS Includes NDCs	1.711	6.4%	1.160	9.6%	1,261
CPS	1.724	5.7%	1.130	13%	1,678
450S 2°C-compatible	1.683	7.9%	1.225	2.5%	499

**Cumulated foreign assets from 2011 to 2032*

Source: Soummane, Ghersi, WP CIRED

Co-development of IMACLIM-country models
A critical challenge to facilitate NDC discussion

- Running
  - Global IMACLIM-R (EMF, IAMC)
  - France
  - Brazil with COPPE-UFRJ
  - South Africa with ERC-CTU
- Expected end-of-year
  - Saudi Arabia with KAPSARC
  - India with PSG-IIMA
  - China with EEE-Tsinghua
- Starting
  - Russia with CENRE-NRU HSE Moscow
  - Argentina with Bariloche F.
- Methodological frontier
  - Informal economies
  - Macro-financial issues and stranded assets threats
  - Link to industrial policies and trade issues ⇨ diversification

Thank you for your attention

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IMACLIM Network webpage under construction at

http://www.centre-cired.fr/index.php/en/imaclim-network/