An Integrated Approach to Energy Modelling in South Africa: The Case for Imported Hydro

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Background

- Electricity in South Africa
  - 90% generation from coal
  - large emitter of greenhouse gases, particularly CO_2 (± 80% of total)
  - Improving access instead of increasing capacity - constrained supply
  - Low real price - rising by about 300% over last 5 years

- Consideration of energy policy: Integrated Resource Plan/Integrated Energy Plan
  - environmental sustainability
  - depleting low cost coal reserves
  - cost competitive alternatives

- Important element of growth strategy → growth, employment and welfare
  - Price impact
  - Investment
  - Other: e.g. ability to localise (how does this fit in with other policies)

Policy Options and Uncertainty

Policy Options

- CO_2 Price/tax level
- Commitment to a Nuclear Program
- Commitment to support a Gas Infrastructure program
- Commitment to support Renewable Program
- Open economy to electricity imports from the region (generated from hydro/gas)

Uncertainty

- Economic growth (and demand for electricity)
- CO_2 Price/tax level
- Global energy commodity prices
- Cost of Nuclear (R/kW) and risk of delays and overruns
- Availability and cost of shale and other gas resource (still under exploration)
- Future cost reductions on RE
- Whether regional projects materialise

Motivation for Linked Energy-Economy-wide Models

- Need tool that can measure the macro- and socio-economic impacts of Energy Policy
- Need tool that can do well “out of sample” for long planning horizon (2035-2050)

- Available tools:
  - Economic Models (General equilibrium)
  - Detailed Energy System Models (partial equilibrium)
- But existing tools are inadequate on their own
  - Economic Models (CGE type): over-simplification of the energy system
  - Energy System Models: no/little economy-energy system feed-back
- We choose the linked iterative approach over full integration:
  - Full inter-temporal integration constrains the level of detail
  - Stakeholders like to see detail they can relate to

- Problem: hard to achieve full coherence between the linked models

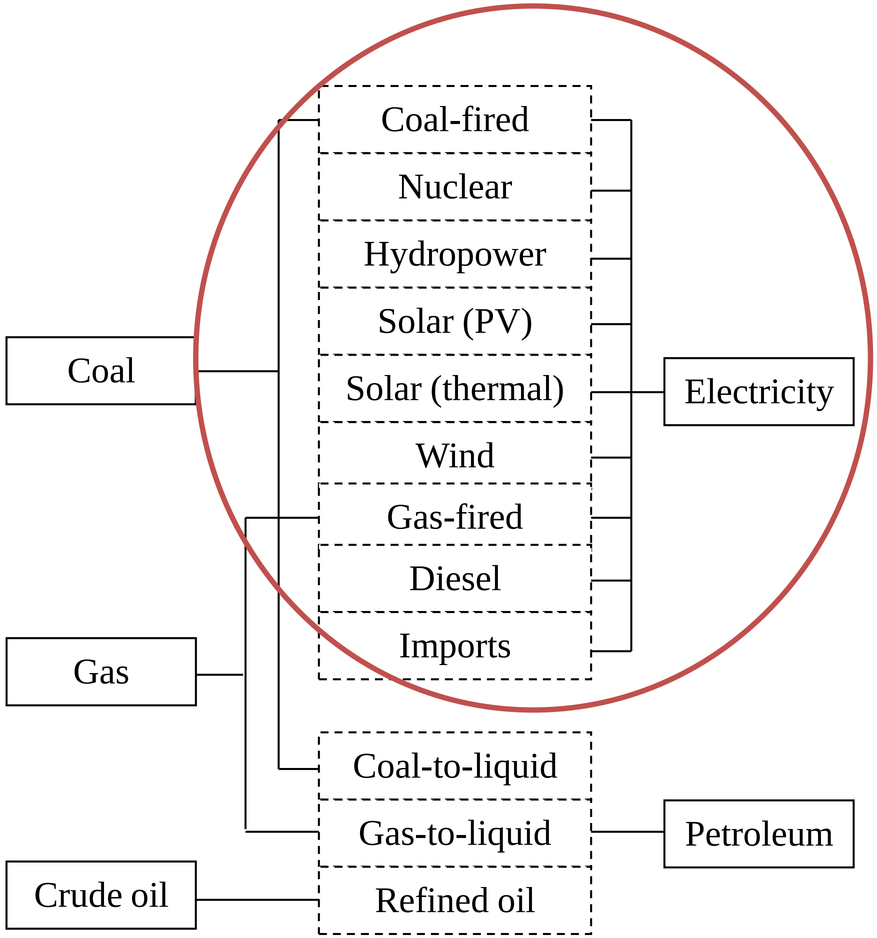
Economic Model (SAGE)

- Standard IFPRI Recursive Dynamic Model
  - Past investment and profitability determines capital accumulation rates
  - Upward sloping labor supply curves
- Additional features:
  - Electricity investments amortized via electricity tariffs (+O&M costs)
  - Energy coefficients are a function of energy prices and investment funds
- 2007 SAM reconciled with an Energy Balance Table
  - 62 sectors; 49 products; 9 factors; 14 representative households
  - Detailed energy subsectors (fuel and power)
  - See Arndt et al. (2012) *SAJE;* Davies and Thurlow (2014) IFPRI SAM

South African TIMES Model (SATIM-el)

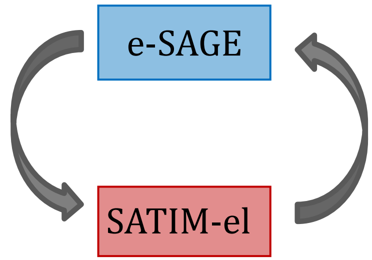
- SATIM-el:
  - TIMES model generator developed by the IEA
  - Inter-temporal optimization partial equilibrium model
  - Here we only use power component (-el)

- Solves for least-cost power plant mix
  - Subject to constraints (i.e., electricity demand; reserve margins; and resource limits)
  - Given system parameters (i.e., load curves; fuel prices; existing plants; new plant options)



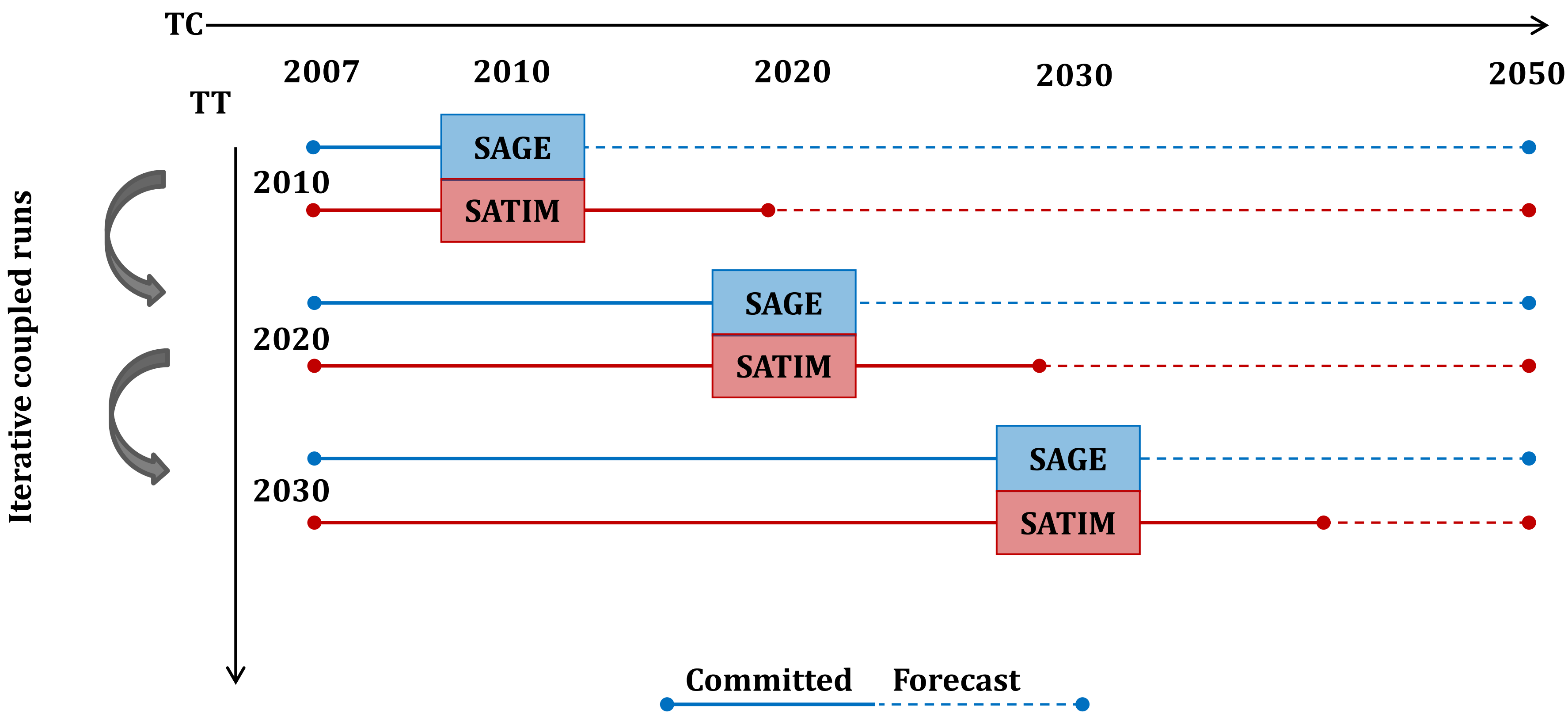
e-SAGE-SATIM-el Iteration Process

Electricity demand

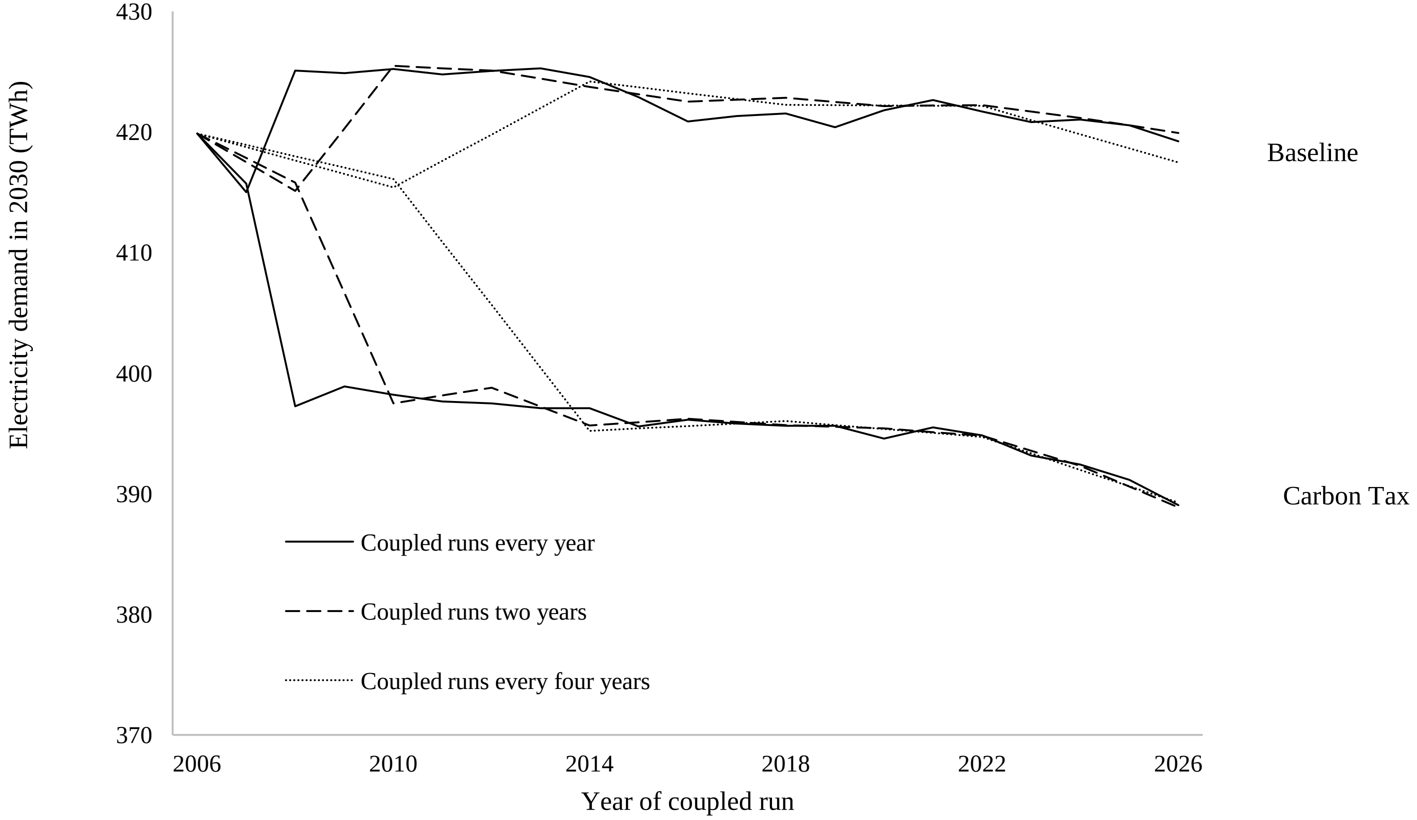


- Electricity production mix by technology/fuel
- Electricity price
- Power plant construction expenditure schedule

Forecast period in annual time steps



Convergence



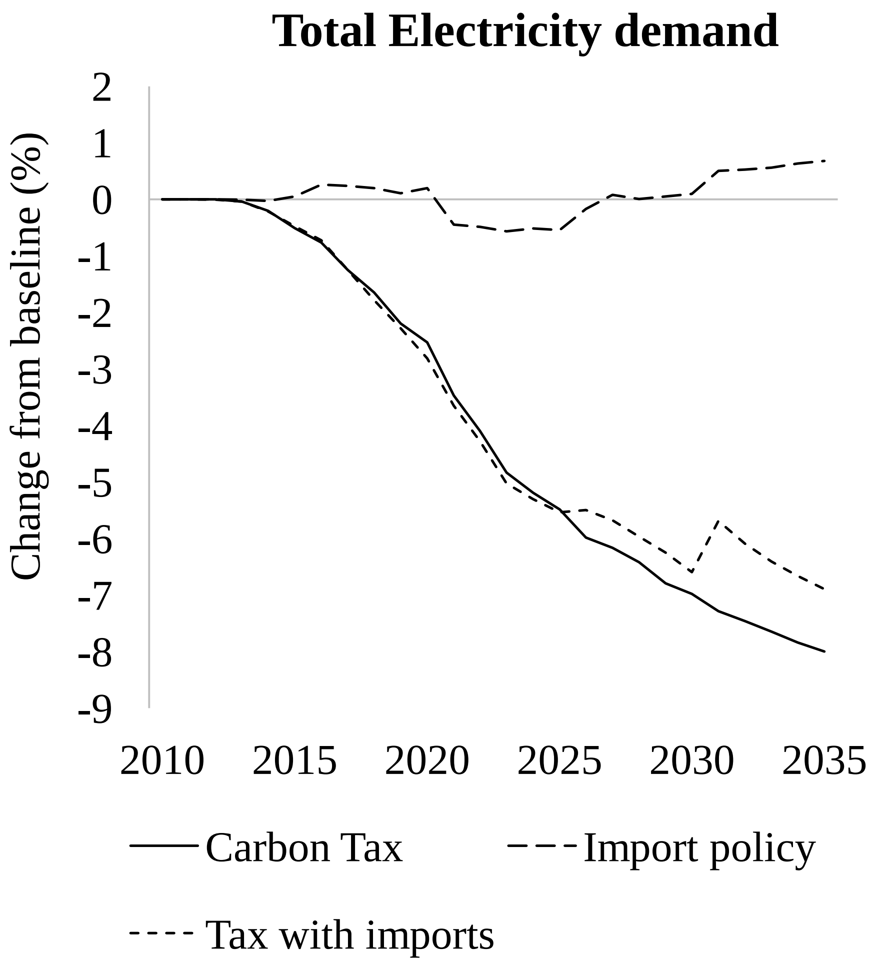
Three Policy Scenarios

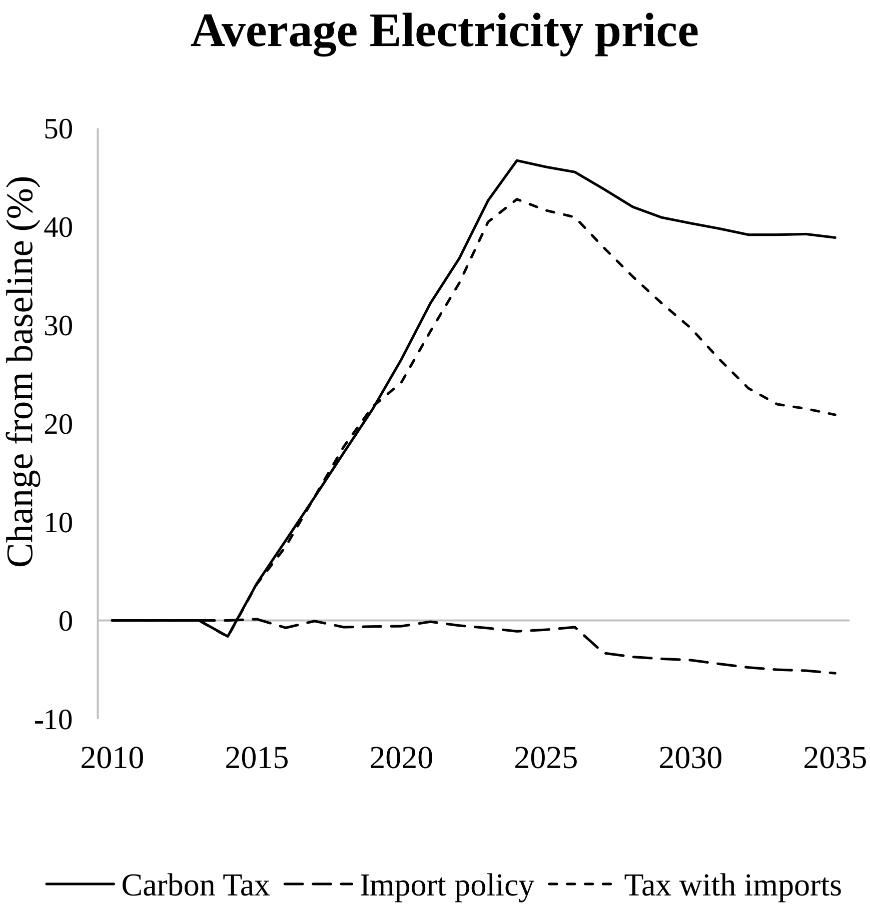
Baseline

- Tracks "business-as-usual" scenario (Alton et al. 2014 *Applied Energy*)
- Includes projected world coal, gas and oil prices

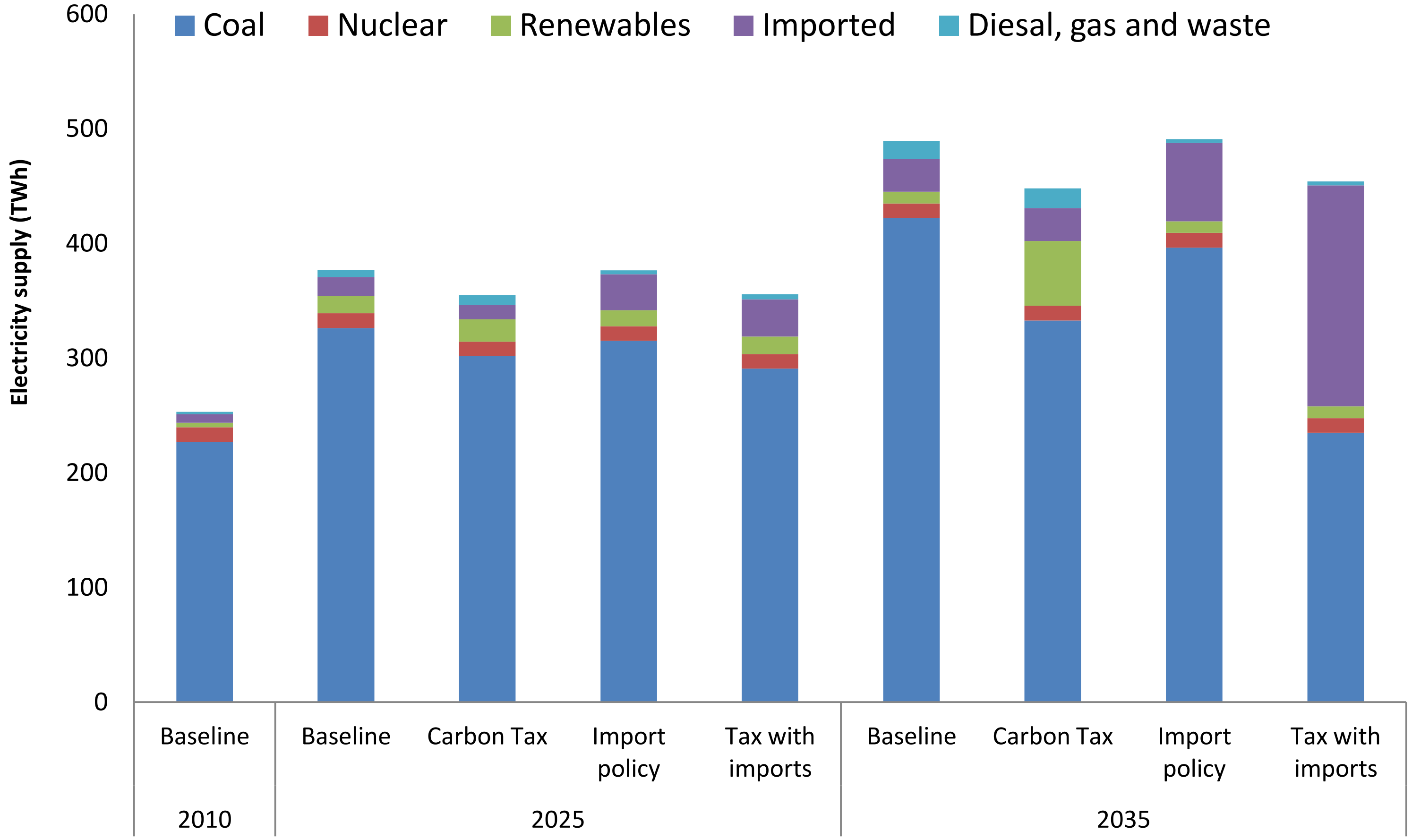
1. Carbon tax
   - US$30 per ton of CO_2 from domestic burning fossil fuels
   - Gradually introduced over 2015-2024
   - Recycle revenues by uniformly lowering indirect tax rates
2. Lift import restrictions (without a carbon tax)
3. Combined "tax with imports" scenario

Electricity Demand and Prices

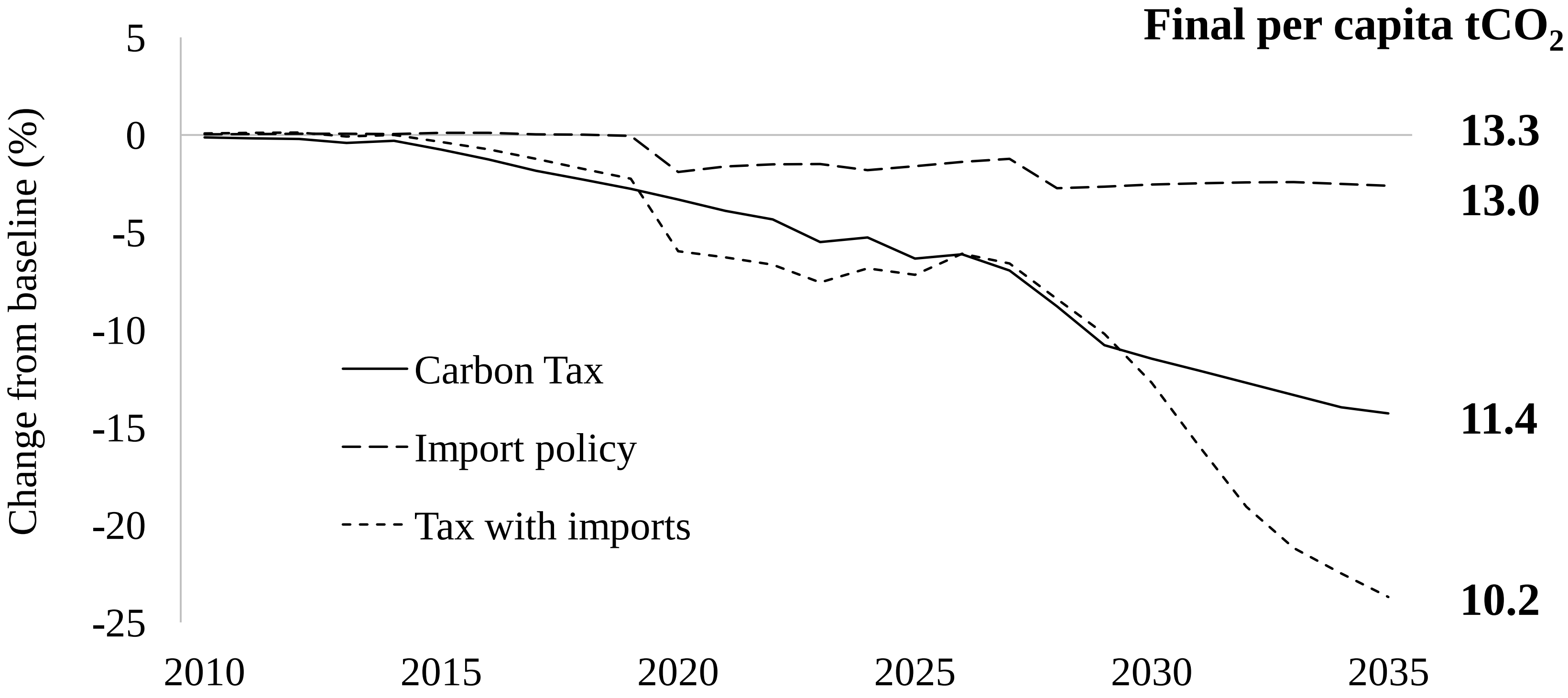




Electricity Supply Mix



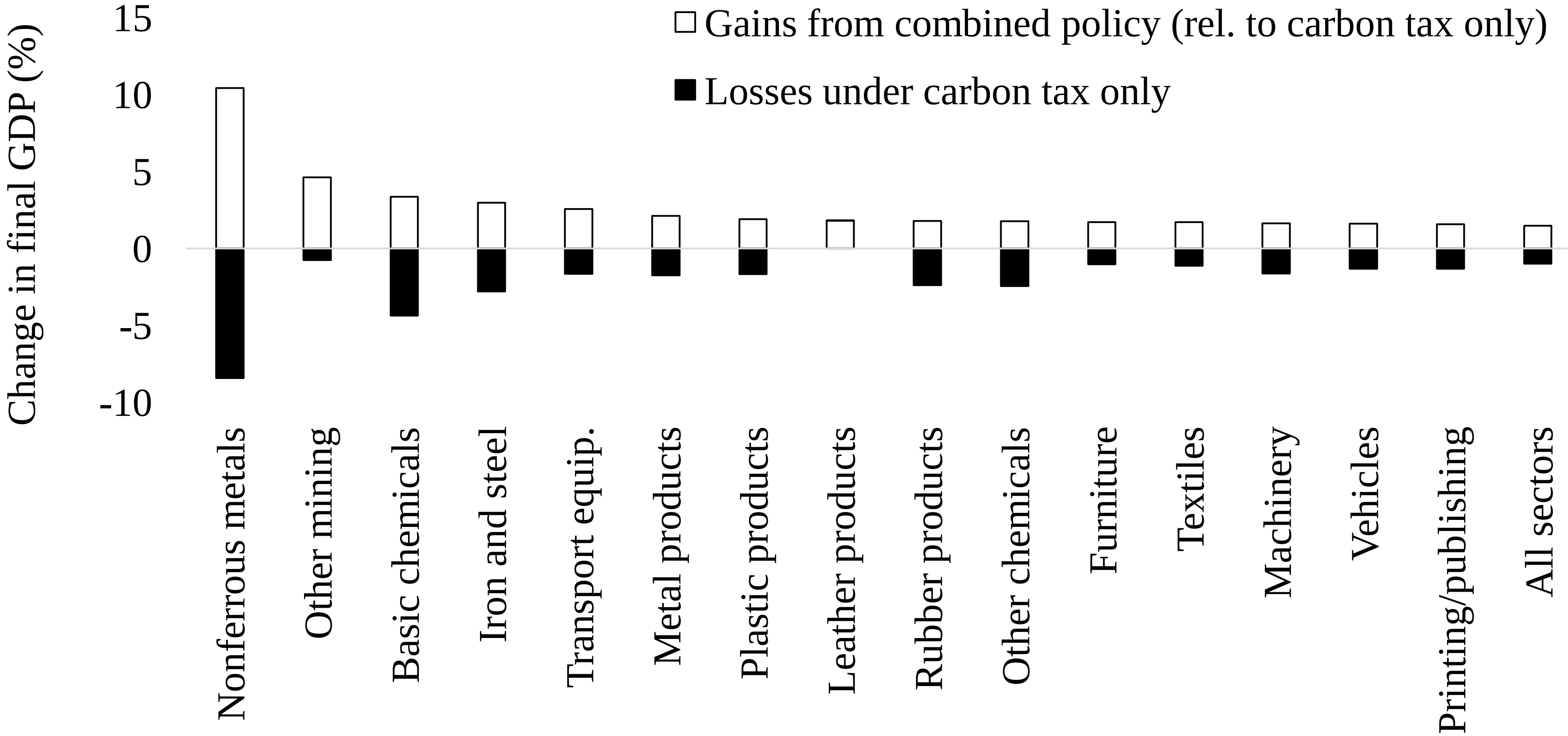
Emissions Reductions



Economic Outcomes

	Baseline	Deviation from baseline, 2035		
		Carbon Tax	Import Policy	Tax with Imports
Cumulative investment cost (US$ bil.)	**94.90**	**19.10**	**-12.70**	**-53.80**
GDP growth (%)	**3.49**	**-0.98**	**0.20**	**0.49**
Employment (%)	1.80	-1.56	0.05	-1.07
Wages (%)	1.15	-1.46	0.14	-0.82
Household welfare (%)	**1.91**	**-0.96**	**0.24**	**0.61**
Low-income (p0-50)	1.93	-1.17	0.24	0.33
Middle-income (p50-90)	1.85	-1.00	0.24	0.53
High-income (p90-100)	1.96	-0.84	0.25	0.79

Sectoral Gains from Combined Policies



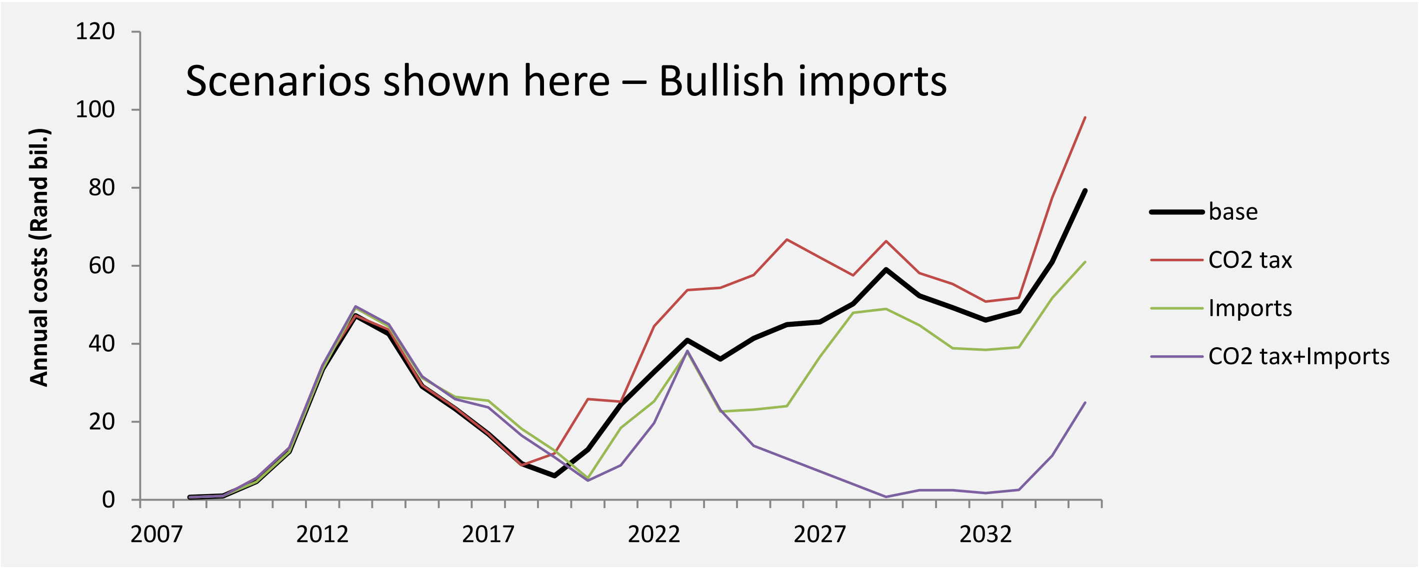
Conclusions

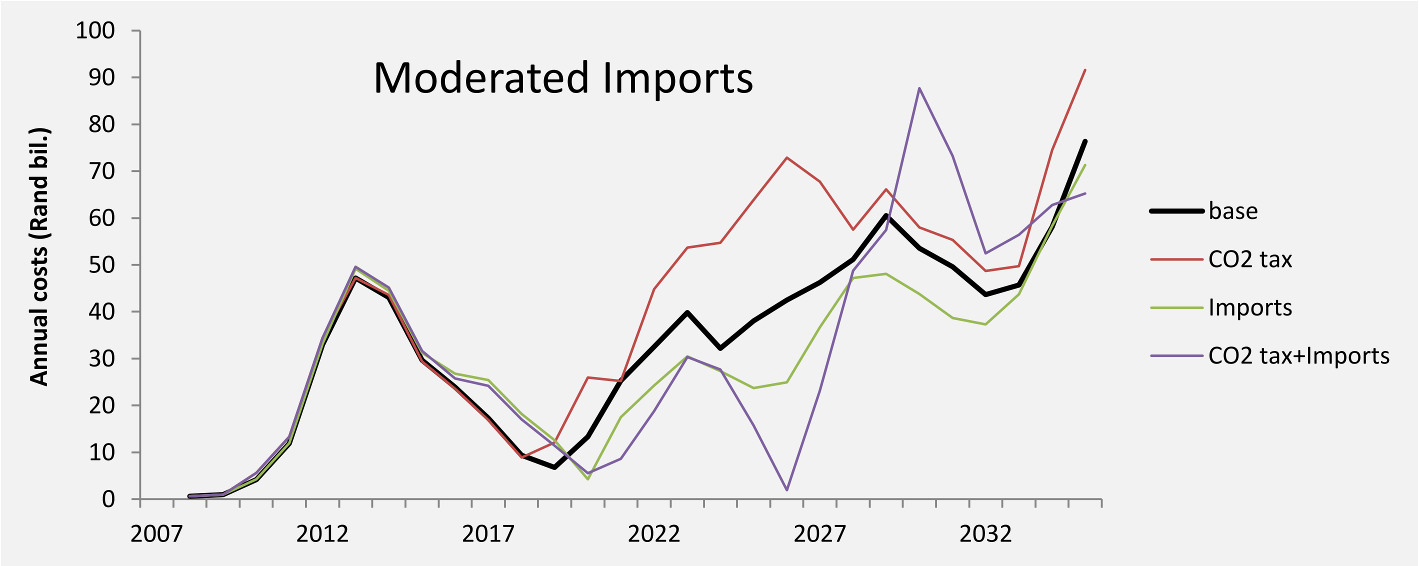
- Carbon tax on its own:
  - Small negative economic impact, incl. reduced household welfare
- Lifting import restrictions on its own:
  - Lowers investment costs and emissions, but gains are small
- Combining a carbon tax with import liberalization:
  - Halves investment costs and meets emissions targets without reducing growth or welfare (but employment falls)
- Regional energy strategy offers a less expensive approach to "decarbonizing" the South African economy
  - Also addresses political economy concerns over adjustment costs

Current and Future Work

- Deep Decarbonisation Pathways Project (DDPP):
  - the linked models used to try and demonstrate development indicators, technology deployment, investment and economic structure trajectories consistent with emissions pathways to achieve the 2°C goal.
- Improving the overall consistency between the two models:
  - Passing the price of labour and investment goods to the energy model (investment and running costs of power plants)
  - Synching the other energy supply sectors: Coal, natural gas, and liquid fuels
- Extending the regional integration work by looking at the potential role of imported biofuels

Power Plant Expenditure Schedule





Growth -0.7%