Sustainability, Modelling and Regional Transition (in Queensland)

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Why are we here?

Brief discussion of the history of the project and why we are here.

- why the project is important to AIBE
- background of regional/sectoral economics at UQ
- Input-Output modelling
- the state of CGE modelling in Australia
  - CoPS, U Victoria (no uncertainty at all or proper dynamics)

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How we arrived at Maiwar: methodology

Recent literature on macroeconomic production networks:

Baqaee–Farhi, . . .

- embeds network modelling in macro models (IO renaissance)
- main finding: nonlinear (beyond Cobb-Douglas) effects matter

Atalay has some good econometric estimates of elasticities

- elasticity of substitution for flows between sectors is about 0.1
- previously most assumed Cobb-Douglas elasticity of 1.0

Conclusion: nonlinear effects matter

- does not bode well for multi-sectoral steady-state approx.
- this includes Baqaee–Farhi, Atalay, CoPS, McKibben

How we arrived at Maiwar: methodology

How about "global" approximation e.g. Value Function Iteration?

Building on Scheidegger's machine-learning approaches, we found

- for 1-sector model, grid approach is (at least) 1 order of magnitude more accurate than steady/ergodic-state approach

But, after a lot of hard work:

- trouble with grid approach: 10^{12} points for 12 dimensions
- approximation is poor outside of grid
- VFI is also unstable (poorly suited to multi-sectoral flows)

A bit more detail on the current state of CGE modelling

- McKibbin 1990s GCube (steady-state, no uncertainty either)
- Malakellis 1990s CoPS (Hamiltonian no uncertainty)
- Ha–Kompas 2017 Hamiltoniann, no uncertainty, impressive.
- Wende 2019, Treasury Intersectoral Model (TIM)

  steady-state, no uncertainty

How we arrived at Maiwar . . . the research question

My old supervisor (Herakles Polemarchakis) once told me that building a model without a question is *the kiss of death*.

Reading group: Aarushi, Marian, Patrick Duenow and I, late 2020.

- Economy-wide implications of mental health: with Patrick D
- COVID impact
- In 2022, settled on 2050 net-zero carbon emission targets.
  - Most economists think Australia will be better off, but
  - Adams 2021, CoPS: Qld -6% GSP and -100k jobs *rel. to base*.
  - What about Qld targets over and above those of Australia?

MAIWAR (Modelling Australian Industry With AMPL Regions)

1. Flexible yet Fast: without steady-state approx
2. Look-forward property: flow of state-action dependent rewards

$$V_{t_0}(\omega_{t_0}) = r_{t_0}(\omega_{t_0}, a_{t_0}) + \cdots + r_{t_9}(\omega_{t_9}, a_{t_9}) + V_{t_{10}}(\omega_{t_{10}})$$

3. Uncertainty: easy way to improve on CoPS
4. Investment/saving behaviour: Euler equations: CGE Dixon–Rimmer 2020
5. Data: BLADE, calibration, econometrics
6. Robust/Reliable: works with a variety of set-ups
7. Accurate/Accessible: John as end-user, as open source as possible
8. Modern yet Trustworthy: best-in-class knowledge, 2+ solvers
9. Scalable: at least to 8 regions and 20 sectors

Cai–Judd's SCEQ: Simple (yet Powerful) Certainty Equivalent Method

E.g. Irreversible risk: one-off, permanent 5% productivity shock.

Loosely resembles tipping points: each year, chance of ice-shelf ...

In this simple example there are 28 paths to 2050:

- path where shock never happens
- path where shock happens in 2023;
- path where shock happens in 2024;
- ...

Each path has 28 periods (PathTimes).

Agents make 10-year plans (LookForward) at each time and path.

Goal: Balance consumption today vs uncertain consumption tomorrow.

On path p: once plan t_0 is made, time reveals state $\omega_{t_1} \rightarrow$ new plan.

What do we (the modeller) do with all this info?

- For each path p and step s along the path, take the plan that starts at time s and store the values for time s.
  - For consumption store in a matrix $C_{s,p}$. The values of this matrix are the solutions for each r in Regions and i in Sectors.
  - similarly for investment $\text{INV}_{s,p}$, labour $L_{s,p}$, kapital $K_{s,p}$, etc.
- *We have generated an empirical distribution of solutions.*
- Can now derive the sample means (paths), variances, etc.
- Check that the Euler equation holds for the sample mean.

Our contribution: multi-sectoral flows

For each Region r, Sector j and LookForward time t:

$$k_{r,j,t+1} = (1-\delta)k_{r,j,t} + s_{r,j,t}$$

where $s_{r,j,t}$ is a CES function of intermediate Long–Plosser flows.

$$s_{r,j,t} = \left(\sum_i \sigma_{ij} S_{r,ij,t}^{\rho} \right)^{\frac{1}{\rho}}$$

From Atalay's model: $\rho = \frac{0.1-1}{0.1} = -9$.

But: 20 Sectors implies 400 flows: $8 \times 400 \times 10 = 32,000$ in total.

Jacobi Equations, for $\mathbf{S}_{r,ij,t} = S_{r,ij,t}/\sigma_{r,ij}$:

$$\mathbf{S}_{r,ij,t} = \mathbf{S}_{r,ik,t} \times \mathbf{S}_{r,kj,t}^{-1} \times \mathbf{S}_{r,kj,t}.$$

Use main diagonal and one column of S: 39 flows with total $3,120$.

The solution for each path for Investment, Kapital and Labour

Cai–Judd: under the bonnet

Why CGE modelling?

- "Old-fashioned", "black-box", "intractible", . . .
- Yet industry demands "CGE" modelling and uses it as a basis for key decisions.
- A guide to quantifying the broader repurcussions of sector-specific shocks.
- A guide to analysing the implications of

Macroeconomics with networks

Why the focus on uncertainty?

There is pretty strong evidence that the rise in uncertainty is a significant factor holding back the pace of recovery now. [...] research shows that heightened uncertainty slows economic growth, raises unemployment, and reduces inflationary pressures. [...] There is no question that slow growth, high unemployment, and significant uncertainty are challenges for monetary policy.

Why not use a CoPS CGE model?

- Cost of software and of data for the model.
- CoPS already have a recent paper on 2050 targets

Moreover:

- no proper savings/investment: intertemporal behaviour
  - leads to strange "macro-closure conditions"
- no model of risk/uncertainty and associated behaviour

CoPS assume current economy is in *Deterministic Steady-State*.

Treasury Intersectoral Model (TIM, 2017)

Part of a new generation of Australian models

J. Miranda-Pinto of UQ had a hand in TIM (and in our choices)

TIM has a sister called EMMA (Macro-econometric forecasting)

- TIM has proper savings
- 114-sector model of Australia
- but no risk
- Deterministic steady state & we can't access

Adapting the Atalay model

Atalay assumes economy in (non-determistic) steady state

- pretty complete and quite good empirical foundations
- we have full access via Matlab & Stata

Our adaptation of Atalay is the first model in our suite.

- less than 1 second to solve a 20-sector model
- regionalise using LGA-level income data via Table Builder
- capital flows matrix by adapting a US flows table from 1997 
- Social Accounting Matrix using Current and Capital Accounts

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Quote from Cai and Judd (Feb, 2021)

Macroeconomists [and CoPS] are often interested in obtaining solutions around the non-stochastic steady state.

However in reality, the initial state could be far away from the steady state, and a policymaker may be more interested in the solutions for the initial periods in the forward-looking model than the far future states that could be around the steady state.

For example, in environmental and climate change economics . . .

The current value function V_0

$$V_0(\omega_0) = \max_{a_\cdot} \quad \mathbb{E}\left\{\sum_{t=0}^{27} \beta^t r_t(\omega_t, a_t) + \beta^{28} V_{28}(\omega_{28})\right\}$$

$$\text{s.t.} \quad \omega_{t+1} = g_t(\omega_t, a_t, \varepsilon_t), \quad t = 0, \ldots, 27$$

$$f_t(\omega_t, a_t) \geq 0, \quad t = 0, \ldots, 27.$$

With current state ω_t, action a_t, expectation $\mathbb{E}$, reward r_t, discount factor $0 < \beta < 1$, terminal value function V_{28}, transition law g_t, error ε_t and feasibility constraints f_t on actions.

- *Once approximated*, iterate over t to get *optimal policy* $a_\cdot^*(\omega_\cdot)$

Thanks for listening!

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