Sustainability, Modelling and Regional Transition (in Queensland)

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April 26, 2022

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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;
- ...

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

Goal: Balance consumption today vs uncertain consumption tomorrow.

On path p: once plan t is made, time reveals state $\omega_{t+1} \rightarrow$ new plan.

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

You throw away everything but the first step in every plan.

The resulting paths of consumption, investment, labour and kapital are essentially samples drawn from the distribution of solutions.

We have generated an empirical distribution.

We can now derive expected paths, variances, et.c.

You can check that the Euler equation holds on average.

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!

Many thanks to the absent members of the team:

- Josh Aberdeen
- Patrick Duenow
- Cameron Gordon