Sustainability, Modelling and Regional Transition (in Queensland)

Patrick O'Callaghan, John Mangan, Tina Rampino

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Presenters

John Mangan

Patrick O'Callaghan

Tina Rampino

Other team members and thanks

Appendix/extra slides

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)

Presenters

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:

► VFI is also unstable (poorly suited to multi-sectoral flows)

► trouble with grid approach: 10^{12} points for 12 dimensions

► approximation is poor outside of grid

MAIWAR model literature

- Solution method: Cai–Judd (2021, 2017)

- Model is a combination of Cai–Judd and Atalay

- Calibration/estimation methods and estimates from Atalay

- But Atalay's solution is not dynamic/stochastic . . .

- We next explain Cai–Judd in some detail.

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 ...

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 Hamiltonian, no uncertainty, impressive.

- Wende 2019, Treasury Intersectoral Model (TIM)
  steady-state, no uncertainty

How we arrived at Maiwar . . . the research question

Herakles Polemarchakis: building a model without a question is *putting the cart before the horse*.

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: 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

Maiwar: the current state of affairs

Currently developing strategies for easy Scaling (pre Calibration).

- ▶ Conopt: for a well-scaled model, all values (variable, dual variable and derivative) in $[10^{-2}, 10^{+2}]$.
- ▶ E.g. Beyond 10 sectors log Cobb-Douglas Utility: *corner sol.*
    - ▶ To help identify scaling parameters: NIMROD, RCC working!
    - ▶ Last Friday: 120 runs in 1 hour on 12 CPUs.

In February, we obtained access to BLADE and established that can use for for government contracts (*not for commercial gain*).

- ▶ Illion Credit-reporting agency: possible BLADE integration ...

Quick interlude on formal model

$$V_0(\omega_0) = \max_{a.} \quad \mathbb{E}\left\{\sum_{t=0}^{9} \beta^t r_t(\omega_t, a_t) + \beta^{10} V_{10}(\omega_{10})\right\}$$

$$\text{s.t.} \quad \omega_{t+1} = g_t(\omega_t, a_t, \varepsilon_t), \quad t = 0, \ldots, 9$$

$$f_t(\omega_t, a_t) \geq 0, \quad t = 0, \ldots, 9.$$

With current state ω_t, action a_t, expectation $\mathbb{E}$, reward r_t, discount factor $0 < \beta < 1$, terminal value function V_{10}, transition law g_t, error ε_t and feasibility constraints f_t on actions.

▶ Grid-free: all about paths ... a simple example.

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 $INV_{s,p}$, 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.

Example of results

Main contribution to Cai–Judd: 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 $3,120$.

Other innovations

So far, the main contributions are:

To CGE: a tractable way of modelling uncertainty.

To Atalay: we take his model beyond the steady-state.

To Cai–Judd: a framework for sectoral/production networks.

Cai–Judd: under the bonnet

For each plan, the terminal value function V_{10} is arbitrary.

One solution is to make longer plans: discount factor $\beta^t \to 0$.

- ▶ Behaviourally unrealistic?
- ▶ Costly computationally …

So best to treat it as another form of parametric uncertainty.

- ▶ Scaling this term: important for avoiding corner solutions.

Checking the Euler Equations in multi-sectoral models is tricky compared to Cai–Judd baseline models.

- ▶ Maximum of deviations from the Jacobi Identity helps here.
  - ▶ my first guide to a good solution.

Data

Late December 2020: lunch with Alicia, discussion of regional
identifiers that had only just been added to BLADE.

- ▶ This represents a unique opportunity for regional modelling
- ▶ Moreover, Type of Activity Units
  - ▶ ABS uses employment data to split larger firms
- ▶ This means upto SA1-level regions and 4-digit ANZSIC
  sectors!

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BLADE: Business Longitudinal Analysis Data Environment

- ▶ Economic data tool integrating tax, trade and intellectual property data with information from ABS surveys

- ▶ Contains data on all active businesses from 2001-02 to 2018-19.

- ▶ We are currently using BLADE Core to construct parameters to scale down the Input-Output tables for Australia.

- ▶ Approx. 2.4 million operating businesses in 2020

- ▶ Patrick and I currently have access and are building variables that will allow us to capture number of TAUs in a given region.

- ▶ Alicia and Martie-Louise are discussants.

BLADE benefits and usage

- ▶ Publicly Available data not granular enough to inform local policy makers,

- ▶ BLADE is especially relevant in the case of Qld (state with the highest regional population)

- ▶ Projects must benefit the public:

- ▶ SMaRT in Qld modelling provides insights on policy interventions

- ▶ "Pulse of the region" industry engagement meetings: DAF interested in assessing the impact of COVID-19 using CGE framework (they think SA4 level, we can model SA1, which is more relevant for rural Queensland)

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 sector-specific implications of macroeconomic shocks

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Thanks for listening!

And many thanks to the absent members of the team:

- Josh Aberdeen (UQ Student Joint Bachelors)

- Patrick Duenow (UQ Student PhD Health Economics)

- Cameron Gordon (U Adelaide Student PhD Machine Learning)

- Alexander Yelkhovsky (Research Fellow Computing)

Also Alicia Rambaldi for her advice on BLADE

Jorge Miranda-Pinto for his expertise on the literature

Brent Ritchie for making the project happen.

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Why the focus on uncertainty?

John Williams (Federal Reserve, San Fransisco):

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.

From Caggiano, Castelnuovo, Groshenny 2015.

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