Sustainability, Modelling and Regional Transition (in Queensland)

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AIBE, The University of Queensland

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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)

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Purpose

Yesterday in conversations with Flavio and John:

- Flavio: CGE is good for long-term problems
- John: real test of success is if we can provide new insights

Key points:

- Maiwar expands the scope of CGE to mid-term problems
- Tools we now have are being applied to design electricity grids

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: Weak-Solutions, 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

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

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

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

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 $\text{INV}_{s,p}$, 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.

Example of results

See spreadsheet and live-run output.

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 for 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)

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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 advice and expertise on the literature

Brent Ritchie for making the project happen.

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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

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-deterministic) 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