The Treasury Industry Model

Macroeconomic Analysis and Policy Division
Macroeconomic Group, Australian Treasury

23 February 2022

Context

- The production side of economy is complex
- Treasury's objectives imply we should be able to provide advice on policy where production complexity needs to be considered
- Treasury needs to harness approaches consistent with mainstream macroeconomic theory

The TIM project

- Treasury has developed a multi-sector dynamic general equilibrium model, called the Treasury Industry Model (TIM)
- TIM provides insight into the effects of industry policy on:
  - Economic activity, government budget, welfare
  - Short, medium and long-run effects of policy
- Based on mainstream macroeconomic theory (neoclassical growth model)
  - But with an increased amount of detail along the firm/industry dimension

TIM Overview – Agents

Households

- Single infinitely-lived representative household
- Forward looking decisions on consumption, leisure/labor, and saving to maximize lifetime utility

Firms

- Each industry is modelled as a representative firm
- Produce using intermediate inputs, labor, capital, and land
- Forward looking decision on investment, output, and production inputs to maximize shareholder value

TIM Overview – Agents

Government

- Levies taxes
- Exogenous spending
- No debt (in any period)

Rest of the World (ROW)

- Perfect capital mobility - foreign investor is the marginal investor
- Differentiated exports and imports

TIM Overview

- A lot of detail, e.g., able to capture price of intermediates inputs by commodity and industry
- Calibrated to Australian data, primarily ABS IO tables
  - 11 margin goods
  - Foreign ownership by industry
  - Sales, excise, duties, production, and capital/labor income taxes
  - Industry specific investment goods
- Captures responses to anticipated policy changes
- Internally consistent welfare measure

Equilibrium conditions

- Have discussed optimal behaviour of agents in model
  - Now need to define equilibrium conditions in the model

Within each time period

- All markets (e.g., goods, labor, capital) clear
- All accounting identities and optimisation conditions hold
- Government has balanced budget

Across time periods

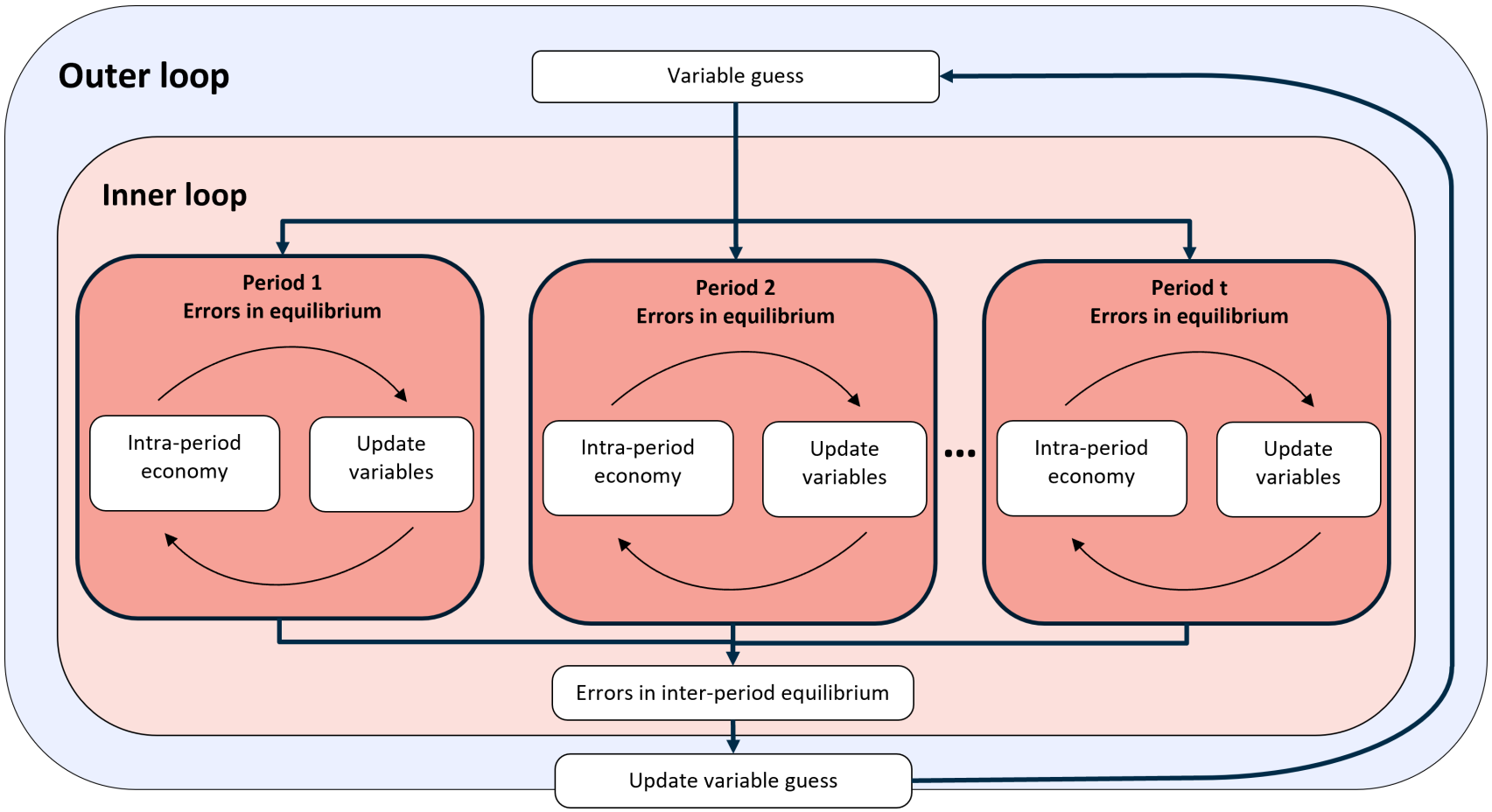
- Intertemporal Euler equation is satisfied
- No incentives for firms to change investment and labor

Solving for an equilibrium

- Guess a set of variables, and verify if all conditions are satisfied
  - If not, update guess and try again
  - Modelling/computational theory help optimise (quicker to solve)

- In TIM, have guesses for:
  - **wages** – labor market clears
  - **prices** and **quantities** – all goods markets clear
  - **government transfers** – govt. budget constraint balances
  - **utility** – household's Euler equation is satisfied
  - **capital** – marginal product condition holds (incl. adjustment costs), and real rate of return must equal to world
  - **labor adjustment costs** – firm's balancing marginal cost/benefit of changing input mix

Graphical view of TIM solution



Implementation

Two-step approach for solving model

- Distinguish between *inter*temporal variables and *intra*temporal variables
- *Conditional* on a set of intertemporal variables, solve each period separately for a set of intratemporal variables
- Then use the resulting set of intratemporal variables to update the intertemporal inputs

Implementation

- Let $\mathbf{X^{INTER}}$ and $\mathbf{X^{INTRA}}$ denote the set of intertemporal and intratemporal variables respectively, where

$$\mathbf{X^{INTER}} = \{U, K_i, LAC_i, MLAC_i\}_t$$

and

$$\mathbf{X^{INTRA}} = \{p_c^y, y_i, w, G^{TRANS}\}_t$$

- $\mathbf{X^{INTER}}$ contains 343 variables (except at time 1) and $\mathbf{X^{INTRA}}$ contains 230 variables, per time period

---

Notation:

- U: utility
- K: capital
- LAC: labor adjustment cost
- $MLAC$: marginal LAC
- p_c^y: domestic price of commodity c
- y_i: output of industry i
- w: wage rate
- G^{TRANS}: value of govt. transfer

Implementation

- Essentially solving a large root finding problem with ~86,000 variables (assuming 150 time periods)

$$\mathbf{f}(\mathbf{X}^{\mathbf{INTER}}, \mathbf{X}^{\mathbf{INTRA}}) = \mathbf{0}$$

- $\mathbf{f}$ is a vector function stacking all general equilibrium conditions (market clearing, intertemporal optimization, balanced constraints) for all time periods
- Could *theoretically* solve all at once using a root-finding algorithm, but *practically* infeasible
- Instead, split up solving into an intertemporal and intratemporal problem

Implementation

- Beginning with a guess of $\mathbf{X^{INTER}}$, and conditional on the guess, solve each time period *separately* for values of X^{INTRA}

$$g_1(X_1^{INTRA} \mid \mathbf{X^{INTER}}) = 0$$

$$\dots$$

$$g_{150}(X_{150}^{INTRA} \mid \mathbf{X^{INTER}}) = 0$$

- Only requires inverting a 230×230 matrix (easy!)

Implementation

- Using the solution for $\mathbf{X^{INTRA}}$ (plus some additional information from the intratemporal solutions), evaluate the *implied* values for the time paths of U, r_i, LAC_i, and $MLAC_i$
- Use these paths to evaluate how far off the guess of $\mathbf{X^{INTER}}$ was from solving $\mathbf{f}(\mathbf{X^{INTER}}, \mathbf{X^{INTRA}}) = \mathbf{0}$
- Update the guess of $\mathbf{X^{INTER}}$ and try again
  - Updating guess is difficult – time periods are linked in this part of the problem
  - Would require inverting a matrix with ∼51,000 variables

Implementation

- Split up the problem yet again
- Three *independent* Jacobians for updating $\mathbf{X}^{\mathbf{INTER}}$
  - Capital by industry, 149×149 (one for each industry)
  - Marginal labor adjustment cost, 150×150 (one for each industry)
  - Utility and aggregate capital, 299×299
- With an update for $\mathbf{X}^{\mathbf{INTER}}$, repeat the process until we find $\mathbf{f}(\mathbf{X}^{\mathbf{INTER}}) = \mathbf{0}$

Conclusion

- TIM is a powerful tool for analysis of policy questions
  - Consistent with mainstream macroeconomic approaches
  - Captures a lot of Australian industry detail
  - Forward looking model useful for considering dynamic aspects of policy
  - Part of Treasury's model development program
- Model is fast, but could be more efficient
  - More ambitious modelling developments may be more computationally intensive