Applied SFC Macro Modelling, Kingston
Agent-Based Stock-Flow Consistent Models

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UWE, Bristol
240 YEARS OF PROGRESS

It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest.

— (Smith [1776] 1976, p. 26–27)

...he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.

— p. 46

For example, in Eggertson and Woodford (2003), an infinitely lived, representative household maximizes utility in a world with complete markets and faces no limit on borrowing against future income.

— Speech by David Miles, Bank of England, 2014
Modelling and abstraction

▶ All models require abstraction; Selecting the correct abstractions is key.
▶ Major theoretical and methodological shift in economics from 1970s
▶ Lucas Critique resulted in insistence that macro models were ‘microfounded’ - constructed using tools of microeconomics.
▶ “If these developments succeed, the term ‘macroeconomic’ will simply disappear from use and the modifier ‘micro’ will become superfluous.” – Lucas
▶ “Interest has shifted from general equilibrium style (high-dimension) models to simple, mainly one-good models ... the representative agent is now usually the model’s driver.” – Bliss
The original impulse to look for better or more explicit micro foundations was probably reasonable. It overlooked the fact that macroeconomics as practiced by Keynes and Pigou was full of informal microfoundations. . . . Generalizations about aggregative consumption-saving patterns, investment patterns, money-holding patterns were always rationalized by plausible statements about individual–and, to some extent, market–behavior. But some formalization of the connection was a good idea.

— Solow, “Dumb and dumber in macroeconomics”
What emerged was not a good idea. The preferred model has a single representative consumer optimizing over infinite time with perfect foresight or rational expectations, in an environment that realizes the resulting plans more or less flawlessly through perfectly competitive forward-looking markets for goods and labor, and perfectly flexible prices and wages. How could anyone expect a sensible short-to-medium-run macroeconomics to come out of that set-up?

— Solow, “Dumb and dumber in macroeconomics”
Key issue is *emergent properties*

Correctly specified microfoundations (e.g. multi-dimensional general equilibrium) will produce aggregate behaviours that diverge from micro behavioural specifications.

Neoclassical representative agent macro instead insists that the macro system exhibits same behaviour as a (utility maximising) individual.
... there is no plausible formal justification for the assumption that the aggregate of individuals, even maximisers, acts itself like an individual maximiser. Individual maximisation does not engender collective rationality, not does the fact that the collectivity exhibits a certain rationality necessarily imply that individuals act rationally. There is simply no direct relation between individual and collective behaviour.

– Kirman
Representative agent macro

- Assumptions required for representative intertemporal consumer:
  - ‘Gorman polar form’ for indirect utility functions: either
    - Individuals have identical and linear Engel curves
    - Individuals have different linear Engel curves but income distribution remains fixed
    - In intertemporal terms, implies constant relative risk aversion: rich and poor are equally averse to proportionate fall in income
  - Contradicts well-known empirical finding that proportions spent on necessities and luxuries change as income increases (Engel’s Law)
  - This isn’t ‘microfounded’ macro … it’s imposing more or less arbitrary restrictions on the micro structure to guarantee a pre-assumed macro behaviour.
A system is typically defined to be complex if it exhibits the following properties:

- The system is composed of interacting units
- the system exhibits *emergent* properties

– Tesfatsion (2005)
Various attempts at definition
  - *Reactive* units
  - Goal-directed reactive units
  - Planner units
  - Tesfatsion (2005)
Schelling Model

Step 1
Schelling Model

Step 2
Schelling Model

Step 3

Diagram of Schelling Model, showing a grid of dots representing locations and colors indicating different groups.
Schelling Model

Step 4
Schelling Model

Step 5
Schelling Model

Step 6

[Diagram of Schelling Model showing Step 6]
Schelling Model

Step 7
Schelling Model

Step 8
Schelling Model

Step 9
Schelling Model

Step 10
Schelling Model

Step 11
Schelling Model

Step 12
Schelling Model

Step 13
Ant colony optimisation algorithm

- Ants initially search at random
- When they find food they return to the colony while laying down pheremone trails
- Ants are attracted to pheremone trails
- Pheremone trails disperse over time
Ant colony optimisation algorithm
Flocking and herding algorithms

- Separation - avoid crowding neighbours (short range repulsion)
- Alignment - steer towards average heading of neighbors
- Cohesion - steer towards average position of neighbors (long range attraction)

https://vimeo.com/2481794
Traditional Keynesian macro

- Specification of aggregate behavioural functions: investment fn, consumption fn etc.
- Often on the basis of empirically observed regularities in the data.
- Apparently incompatible with standard optimising microeconomic theory.
- Lacking microfoundations?
Traditional Keynesian macro

- Shaikh (2016) model
- Assume a necessary good and a luxury good
- Assume some minimum level of consumption for the necessary good
- Four type of micro behaviour and structure:
  - Homogeneous neoclassical optimisers
  - Heterogeneous neoclassical optimisers
  - ‘Whimsical’ agents
  - ‘Imitate-innovate’ agents
All actual elasticities are listed in table 3.1. It is evident that the very different micro...

Figure 3.10 Necessary Good (x₁) Demand Curves, Four Different Micro Foundations
Traditional Keynesian macro

- Stable macro consumption function emerges, regardless of microfoundations
- Macro behavioural specifications should be rooted in plausible micro behavior and restrictions
- Not all will carry through to macro level
- Examples:
  - Keynes’ consumption function
  - Kalecki pricing model
  - Friedman demand for money
- “Aggregation is robustly transformational” (Shaikh, 2016)
- Macro aggregate relationships can stake a better claim to be “microfounded” – even if we don’t know what the microfoundations are.
- Shouldn’t stop us trying to find out . . .
Agent-Based What?

ABMs

ACE

Macro ABMs

Macro SFC ABMs
Agent-based Computational Economics (ACE) is the computational modeling of economic processes (including whole economies) as open-ended dynamic systems of interacting agents ... These principles reflect the fundamental goal of many agent-based modelers: namely, to be able to study real-world dynamic systems as historical processes unfolding through time, driven solely by their own internal dynamics.
1. Agent Definition: An agent is ... capable of acting over time on the basis of its own state, i.e., its own internal data, attributes, and methods.

2. Agent Scope: individuals, social groupings, institutions, biological entities, and/or physical entities.

3. Agent Local Constructivity: The decision-making process ... entirely expressible as a function of the agent’s state at that time.

4. Agent Autonomy: Coordination of agent interactions over time cannot be externally ... 

5. System Constructivity: State of modeled system at any given time consists of the collection of agent states at that time.

6. System Historicity: Given initial agent states, all subsequent outcomes determined solely by agent interactions.

7. Modeler as Culture-Dish Experimenter
Macro ABMs

- ACE framework applied to macro questions and issues
- Use of simulation overcomes problems of analytical difficulties of ‘general equilibrium’ systems
- Opens up possibility of analysis of:
  - Inequality of wealth and income (personal, household, wage etc.)
  - Uneven distribution of corporate size, strength, power
  - Modelling of market process: trading, production, distribution
  - Financial interaction and financial structure
  - *Endogenous* processes: not external shocks
- But there isn’t much *macro* in many AB macro models.
**Stock-flow consistent models**

- Name is unhelpful, as Lavoie emphasises (DSGE models are internally consistent).
- Refers to a narrower set of features
  - Flow of funds accounting
  - ‘Cambridge Keynesian’ macro behavioural equations.
  - Tobin-style portfolio allocation behaviour
- Synthesis of ‘true’ macro modelling with a non-neutral monetary and financial system
- Sectoral financial balances is a key feature . . .
- . . . and also a key shortcoming.
**Financial Balances**

\[ S = I \]

\[ S_P - I_P = G - T \]

\[ (S_P - I_P) = (G - T) + (X - M) \]

\[ (S_H - I_H) + (S_F - I_F) = (G - T) + (X - M) \]
## Transactions Flow Matrix

<table>
<thead>
<tr>
<th></th>
<th>Households</th>
<th>Business</th>
<th>Government</th>
<th>Σ</th>
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<td>+C</td>
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<tr>
<td>Taxes</td>
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<td>−Investment</td>
<td>−Deficit</td>
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*Table 1. Simplified National Income Matrix*
### Transactions Flow Matrix

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<td></td>
<td>0</td>
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<td>−ΔL</td>
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*Table 2. Transactions Flow Matrix*
Britain is heading for another 2008 crash: here’s why

David Graeber

The government wants us to believe our economic growth is sustainable, and that budgetary surplus will fix all our problems. But these are dangerous myths
FINANCIAL BALANCES

What this means is that if the government declares “we must act responsibly and pay back the national debt” and runs a budget surplus, then it (the public sector) is taking more money in taxes out of the private sector than it’s paying back in. That money has to come from somewhere. So if the government runs a surplus, the private sector goes into deficit. If the government reduces its debt, everyone else has to go into debt in exactly that proportion in order to balance their own budgets.

But something along these lines has to happen when the government runs a surplus. Everyone will just keep pushing the debt on to those least able to pay it, until the whole thing collapses like a house of cards: just like it did in 2008.
Figure 12 The Three Major Financial Balances, Actual 1970–1999Q1 and Projections Implied by CBO

Note: Data after 1999Q1, where the vertical line is now drawn, are author’s projections.
Source: Citibase, Flow of Funds, and author’s projections.

From Godley, “Seven Unsustainable Processes”, 1999
tion, or investment. The private financial deficit measures something straightforward and unambiguous; it measures the extent to which the flow of payments into the private sector arising from the production and sale of goods and services exceeds private outlays on goods and services and taxes, which have to be made in money. While capital gains step; money balances must be run down (surely a very limited net source of funds) or there must be net realizations of financial assets by the private sector as a whole or there has to be net borrowing from the financial sector. Furthermore, a capital gain
**Figure 13** Private Financial Balance and Growth of Nonfinancial Debt, Actual 1970–1999Q1 and Projections Implied by CBO

*Note: Data after 1999Q1 are author’s projections.*

*Source: Citibase Flow of Funds and author’s calculations.*

From Godley, “Seven Unsustainable Processes”, 1999
Example: Housing Purchase
Example: Housing Purchase

The house buyer takes out a mortgage...

Buyer and seller's banks

Buyer's bank

Assets
New loan
Reserves
Currency

Liabilities
New deposit
Deposits
Currency

Seller's bank

Assets
New deposit
Reserves
Currency

Liabilities
New loan
Deposits
Currency
Example: housing purchase

...and uses its new deposits to pay the house seller.
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*Table 2. Transactions Flow Matrix*
Example: Shadow Banking

- Creditor
  Assets Liabilities
- MMF
  Assets Liabilities
- Dealer/Broker
  Assets Liabilities
- Mortgage Bank
- Debtor
Example: Shadow Banking

1. Loan origination
   Creditor
   Assets Liabilities

   MMF
   Assets Liabilities

   Dealer/Broker
   Assets Liabilities

   Mortgage Bank
   Assets Liabilities
   Loans Deposits

   Debtor
   Assets Liabilities
   Deposits Loans
Example: Shadow Banking

2. Spending

Creditor
Assets       Liabilities

Deposits

MMF
Assets       Liabilities

Dealer/Broker
Assets       Liabilities

Mortgage Bank
Assets       Liabilities

Loans       Deposits

Debtor
Assets       Liabilities

Loans
Example: shadow banking

3. MMF share purchase

Creditor
Assets: NAV shares
Liabilities

MMF
Assets: Deposits
Liabilities: NAV shares

Dealer/Broker
Assets
Liabilities

Mortgage Bank
Assets: Loans
Liabilities: Deposits

Debtor
Assets
Liabilities: Loans
Example: Shadow Banking

4. MMF repo D/B

Creditor
Assets Liabilities

NAV shares

MMF

Assets Liabilities

Repo NAV shares

Dealer/Broker

Assets Liabilities

Deposits Repo

Mortgage Bank

Assets Liabilities

Loans Deposits

Debtor

Assets Liabilities

Loans
Example: Shadow Banking

5. Deposit extinguished

**Creditor**
- Assets
  - NAV shares
- Liabilities

**MMF**
- Assets
  - Repo
- Liabilities
  - NAV shares

**Dealer/Broker**
- Assets
  - Repo
- Liabilities
  - Repo

**Mortgage Bank**
- Assets
  - Loans
- Liabilities
  - Repo

**Debtor**
- Assets
  - Loans
- Liabilities
Example: Minsky

- Over the course of the boom, firms increase debt-financed investment
- Leverage ratios grow for the economy as a whole
- Financial instability increases
- Crisis
Example: Minsky

\[ Y = W + \Pi = C + I \]  \hspace{1cm} (1)

\[ W + \Pi = (C_W + C_C) + I \]  \hspace{1cm} (2)

\[ \Pi = C_C + I - W + C_H \]  \hspace{1cm} (3)

Assume \( C_W = W \) and \( C_C = 0 \).

\[ \Pi = I \]  \hspace{1cm} (4)

“Workers spend what they get and capitalists get what they spend” (Joan Robinson)
Example: Minsky

Minsky can be rescued if sectoral financial balances shift:

\[ \Pi = C_C + I - W + C_H \] \hspace{1cm} (5)

\[ \Pi = C_C + I + S_H + (G - T) + (X - M) \] \hspace{1cm} (6)
Financial balances

Chart 3.39: Sectoral net lending

Source: ONS, OBR
Consolidated balance sheet of corporate non-financial sector

- **Real assets**
- **Financial assets**
- **Liabilities**
- **Debt**
- **Equity**
- **Net worth**

**Time**


**Financial balances**

59 / 63
Cash payment commitments on outstanding instruments are contractual commitments to pay interest and repay the principal on debts and to pay dividends—if earned—on equity shares. These cash payment commitments are money flows set up by the financial structure. A structure of expected money receipts underlies the various commitments to make payments. Each economic unit—be it a business firm, household, financial institution, or government—is a money-in-money-out device. The relation among the various sources and uses of cash for the various classes of economic units determines the potential for instability of the economy.

SFC ABM

- Well-suited to modelling financially developed systems
- Financial market structures and processes
- Monetary dynamics
- Asset price dynamics
- Distributional issues in a financially advanced system
- Network structures, stability etc.
Modelling considerations

- ABM raises order of complexity significantly. Think carefully!
- Consider what kinds of reactive behaviour and feedback you want to include
  - Reaction to environment - other agents, institutional structure, exogenous policy
  - Reaction to own conditions - e.g. leverage ratio
  - Are reactions functions smooth or are there non-linearities (tipping points)?
Modelling considerations

Consider what type of heterogeneity you want to include

- Hard-coded differences in behaviour, expectations formation - e.g. patient and impatient consumers.
- Heterogeneity in state, not agent attributes
- Do you need heterogeneity in all sectors of your model?

Once you are not solving simultaneous equations, sequencing matters. In what order are decisions made, actions taken?

Start simple / small.