The (realized and Potential) Contributions of Agent Based Models to Macroeconomics

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Outline

Complex vs Equilibrium

Solow’s Wager: DSGE+

The Full Monty: Million Agent Worlds

The Potential
Properties

Equilibria, patterns, randomness, complexity

Robust

Large Events, Long Tail Distributions

Self Organization

Emergence

Accounting and Physical Laws
Solow’s Wager

DSGE + heterogeneous agents + adaptation + network effects = complex system
Incomplete Markets

Heterogeneity from risk: winners and losers

Implications:

“identical” people vary in C,I,W
Risk heterogeneity interacts with preference and endowment heterogeneity
Incomplete Market Effects

Prices and quantities via savings and taxes
  Heathcoate (2005, 2011)

Welfare effects of variability
  Lucas (1987), Storesletten et al. (2001)
Unanswerable

• Bankruptcy

• Unemployment Insurance
  – Hansen and Ayse Imrohoroglu (1991)

• Geographic Dispersion

• Safety Net Policies
  – Nishiyama and Smetters (2007)
I must end this sub-section with a cautionary caveat. I often hear the objection to the foregoing telegraphic, inevitably rough, account, that new macro theory, in the form of the newest generation of DSGE models, takes on board various forms of “imperfections”, “frictions”, “inertias” (cf. Blanchard, 2009, and Woodford, 2009, for bold claims on the DSGE – “New Keynesian Synthesis”). True, we are now in the late-Ptolemaic phase of the theory: add epicycles at full steam without any empirical discipline and you will get some greater possibilities of calibration of the model (“calibration” is the new game in town, often not too short of voodoo: see also below). Of course, in the epicycles frenzy one is never touched by the sense of ridiculous in assuming that the mythical

Givoanni Dosi’ (2011)
The Full Monty: Million Agent Worlds
Two Part Harmony

**Individuals:** Ecology of diverse behaviors produced by diverse and evolving models of how the world works that produce dynamic patterns. Short term survival of the “reckless”

**Firms:** Fortunes are stochastic, interdependent. Firms growth independent of size (but variability reducing in size). Firms differ in organizational ability to adapt. Selection matters less than changes in productivity.
Stock Market Model

Assumptions:
Trading rules: heterogeneous
Accurate market micro structure
Wealth Distribution: emergent
Fit to data: no

Lebaron, Blake Agent-based Financial Markets: Matching Stylized Facts with Style, in Post Walrasian Macroeconomics: Beyond the DSGE Model,
Stock Market Model

**Objective:** *Fit stylized facts/explain puzzles*

Volatility: persistent (1 year), kurtosis

Equity Premium Puzzle

Volume: enormous (NYSE, a trillion a month)
Assets:
  Equity: growth $N(2\%, 6\%)$
  Cash: int rate 0%

Agents:
  Consumption: constant wealth fraction
  Long memory and short memory traders
  – 250 Rules based on Lagged returns Dividend/Price ratios Price momentum
  – Neural network
  Bankrupt: replaced

Time Period:
  One week
Price Versus Equilibrium Price
S&P 500 and “Rational” Price
(Shiller)
Absolute Return Autocorrelations
Weekly Returns

![Graph showing absolute return autocorrelations for S&P and simulation.](image)
Housing

Prepayment decisions

2.2 million agents

Fit to data
Housing

Objective: Improve on old model of prepayment, leverage or interest rates

Old Model:
\[ f(\text{age}(t), \text{seasonality}(t), \text{ratechange}(t), \text{burnout}(t), \text{parameters}) \]

Parameters: age, etc..

Burnout = sum of rate change in previous periods
Base Model

**Agent** \((c, a, p)\)
\((\text{cost, alertness, prob sell house})\)

Cost\((t)\) decreasing
Alertness\((t)\) increasing
Probsell\((t)\) = \(f(\text{parameters})\)

Note: burnout emerges from cost of selling and alertness
Figure 1. Conditional Prepayment Rate Projections Can Be Very Reliable in an Agent-Based Model

8% Coupon 1986
``In the first decade of 2000 a new feature appeared, the cash out refinance. Homeowners began to refinance their mortgages even when interest rates barely dropped, or rose, in order to get bigger loans.’’

``This illustrates the standard criticism of agent based models, that behavioral rules eventually become inappropriate (or in need of revision) as the world changes. ‘’

Advanced Model

Agent: (income, wealth, equity, age, etc..)
Data matched to PSID

Selling Behavior: start at 10% above market and lower 3-5%
Buying Behavior: want to spend 30% of income

Note: full model still in process
Axtell’s Labor Market
Objective: construct a model that produces static characteristics of both firms and labor market

Firm Distribution: firm size, growth, age, output, turnover, productivity as well as worker income, job tenure.

E.g. of the largest 5000 U.S. firms in 1982, in excess of 65% of them no longer existed as independent entities by 1996

Firm Dynamics growth rates declining with age, growth rate variance that falls with size and age, and approximately constant returns to scale at the aggregate level.

Labor Market: Job-to-job flows, hiring, unemployment
Agents:
cobb-douglas U(income,leisure)
ability
effort

Firms:
productivity = f(Σa,n)  df/da > 0, df/dn <0
profits split among workers

Adaptation:
4% of 120 million agents activated
consider moving to new firm (job to job)
work along

Fundamental Instability
workers join larger, more productive firms
but then have incentives to shirk, so workers leave
Figure 17: Firm survival probability increases with firm age, U.S. data 1994-2000 (lines) and model (points), and firm size; source: BLS and author calculations

Figure 14: Firm age distributions \((pmfs)\), U.S. data 2000-2011 (lines) and model output (points); source: BLS (www.bls.gov/bdm/us_age_naics_00_table5.txt) and author calculations
Figure 11: Stationary firm size distributions (probability mass functions) by (a) employees and (b) output
Micro to Macro

If Micro Assumptions Approximate:
worker movements between firms
firm productivities and size

Then Macro Correct in Pattern
size, Income, age, wealth distribution
job turnover
Economy Wide

Firms, Households distributionally approximate Consumption
Firm Competition
Labor Supply
Financial Markets
Policies

Herbert Dawid, Simon Gemkow, Philipp Harting, Sander van der Hoog, and Michael Neugart, "The Eurace@Unibi Model: An Agent-Based Macroeconomic Model for Policy Purposes" [1]
Eurace Unibi Model
Potential
Alternative Discipline
DSGE: Logic

ABM: Data, Distributions, Behaviors
Different/More Data
Google Search Trends: "mortgage rates" (Canada 2004-2012)
Solve the
“Find the Largest Integer Problem”
Trends: The Second Eigenvalue
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Ubiquity: 2 4 2 1
HH-Complexity

$M = \text{normalized diversity/ubiquity matrix}$

$MM'$ gives ubiquity weighted diversity

Complexity = second eigenvector of $MM'$
Complexity Rankings over Time
Income and Complexity

Economic Complexity Index controlling for initial income and resource endowment

\[ R^2 = 0.73 \]
Weakness as Strength
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Beveridge Curve
Transcience
Robustness vs Stability
**Stability:** return to same or nearby equilibrium

**Robustness:** ability to maintain functionality to external trauma and internal dynamics. The diversity of the parts and complexity of the process contribute to robustness.
Heterogeneity and Crashes
Let’s Play Two
Diversity Prediction Theorem

\[
(c - \theta)^2 = \frac{1}{n} \sum_{i=1}^{n} (s_i - \theta)^2 - \frac{1}{n} \sum_{i=1}^{n} (s_i - c)^2
\]