Agent-based Computing in Economics and other Social Sciences: Prospects and Opportunities

CABDyN

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20th C vs 21st C Social Science

Homogeneous agents:

the representative agent
a few agent 'types'
continuum of agent types
single agent institutions
antidote: Kirman [1992]

Rational actors:

complete, reflexive, transitive, continuous, monotone preferences
scalar value function
max U, max profit, min cost
decision theory, math programming
antidotes: Simon [1956], Kirman [1993]

Well-mixed populations:

centralized information, control
no direct interactions
methodological atomism
antidote: Kirman [1997]

Equilibrium: the 'Nash' program

Macro just magnified micro

Heterogeneous agents:

local agent data
homogeneous rules, heterogeneous behavior
heterogeneous rules of behavior
early example: SFI Stock Market

Bounded rationality:

zero-intelligence/'best reply'/heuristics
adaptive/behavioral/learning models
BDI framework, aspirational models
full-blown cognitive models (e.g., SOAR)
behavioral game theory
example: El Farol model (Arthur)

Networks:

social networks (sociology)
technological networks (computer science)
mathematics of networks (physics)
rational networks (economics)

Disequilibrium at agent level

Macro emerges from micro

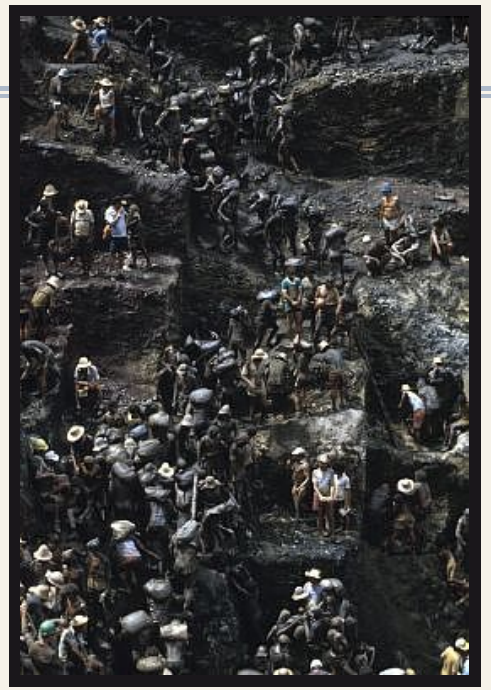
'Big data' (micro-data)

Revolution in the Social Sciences:

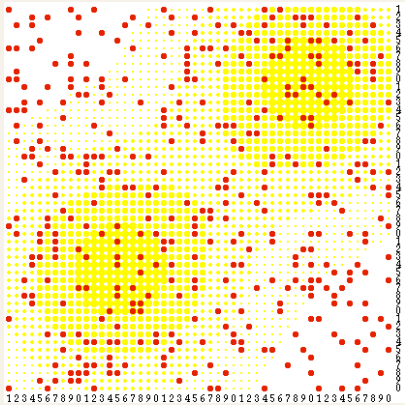
Complex (20th C) vs Simple (21st C)

Global information	Local information
Scalar value function (utility, profit, market capitalization)	Diverse representations, competing world views
Rational people, firms	Behavioral agents
Single decision-maker (decision theory works)	Multi-agent institutions (everything is game theory)
Mean field (averages work, variances are finite)	Networks, heavy tails (infinite variance), extremes
Continuous, smooth math	Discrete math, computation
Equilibrium, fixed points	Adaptation, co-evoluiton
Markets: law of one price	Auctions: heterogenous *p*'s
CS: Top down AI	CS: Distributed AI and MAS
Centralized *control*	Emergence from bottom up

What are Agent-based Systems?



- Population of software *agents*
- Rules for agent-agent *interactions*
- Systematic software engineering with *objects*
- Many ‘flavors’ today:
  - CS: multi-agent systems (MAS)
  - ecology: individual-based models (IBMs)
  - social science: agent-based models (ABMs)



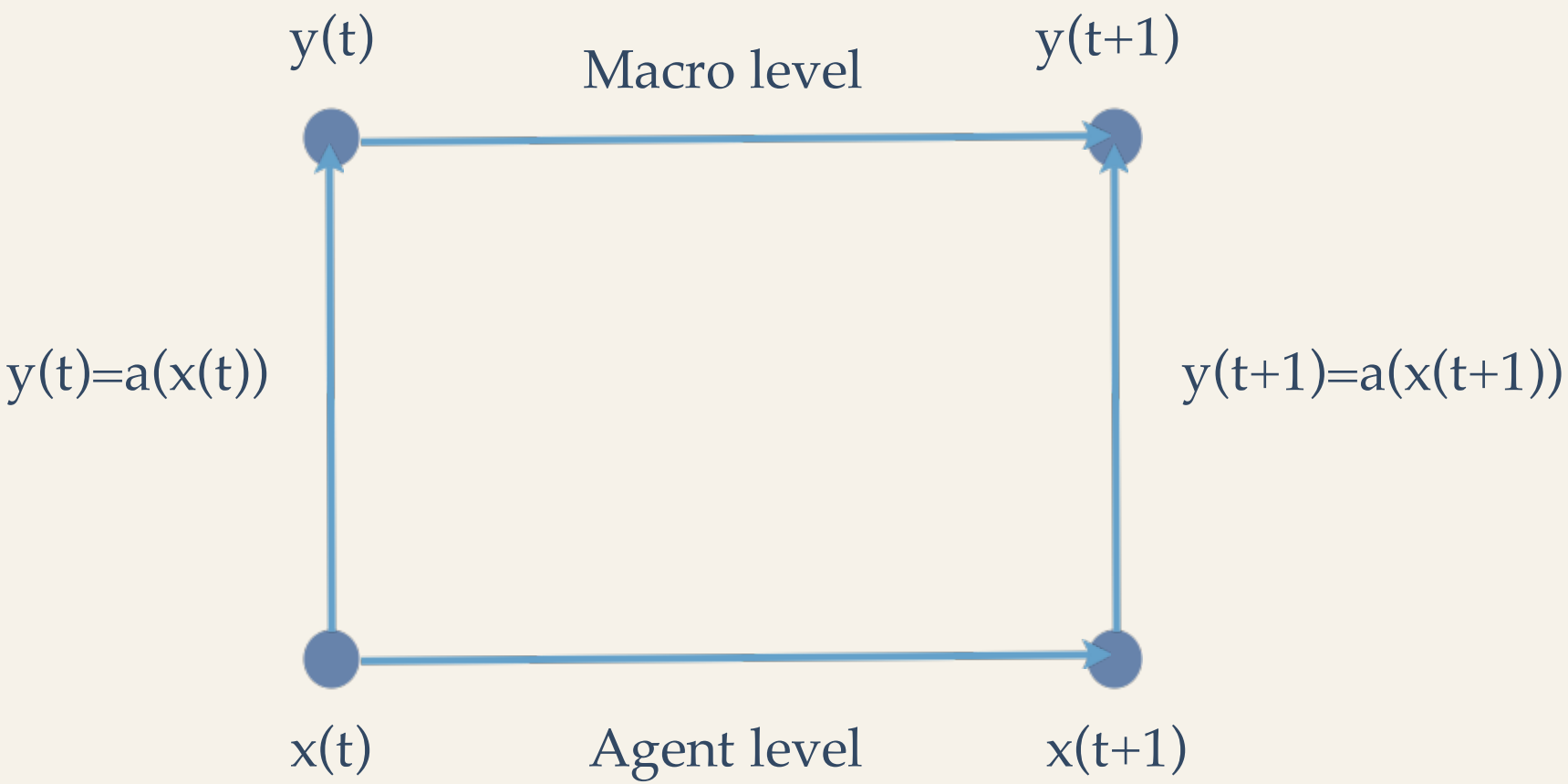
Agents in the Social Sciences

- Schelling's early work (1969-71) *concurrent* w/Tullock+Campbell (1970)
- Anthropology: SIG on agent-based computing in the AAA
- Political science and policy: Axelrod and students, Laver and Sergenti
- Sociology: Macy, Hedstrom (*Analytical Sociology*), Billari (demography)
- Geography: Batty and students (Crooks, Torrens): GIS + agents
- Epidemiology: EpiSims (Los Alamos), Longini (CDC), MIDAS (NIH),...
- Economics: Tesfatsion, Kirman, Vriend, Duffy, Arifovic, Gallegati, EURACE project, Delli Gatti, Dawid, Neugart, Page, Tassier, Ussher,...
- Finance: LeBaron, Lux, Chiarella, econophysicists, CRISIS project,...
- Societies: ESSA, CSSSA, PAAA/PRIMA, MABS/AAMAS,...

What Problems to Agents Solve?

- Agent heterogeneity
- Bounded rationality
- Networks
- Agent-level disequilibrium
- Multi-level character of social systems...
  - How 'more can be different'

Social Systems as Multi-Level Systems



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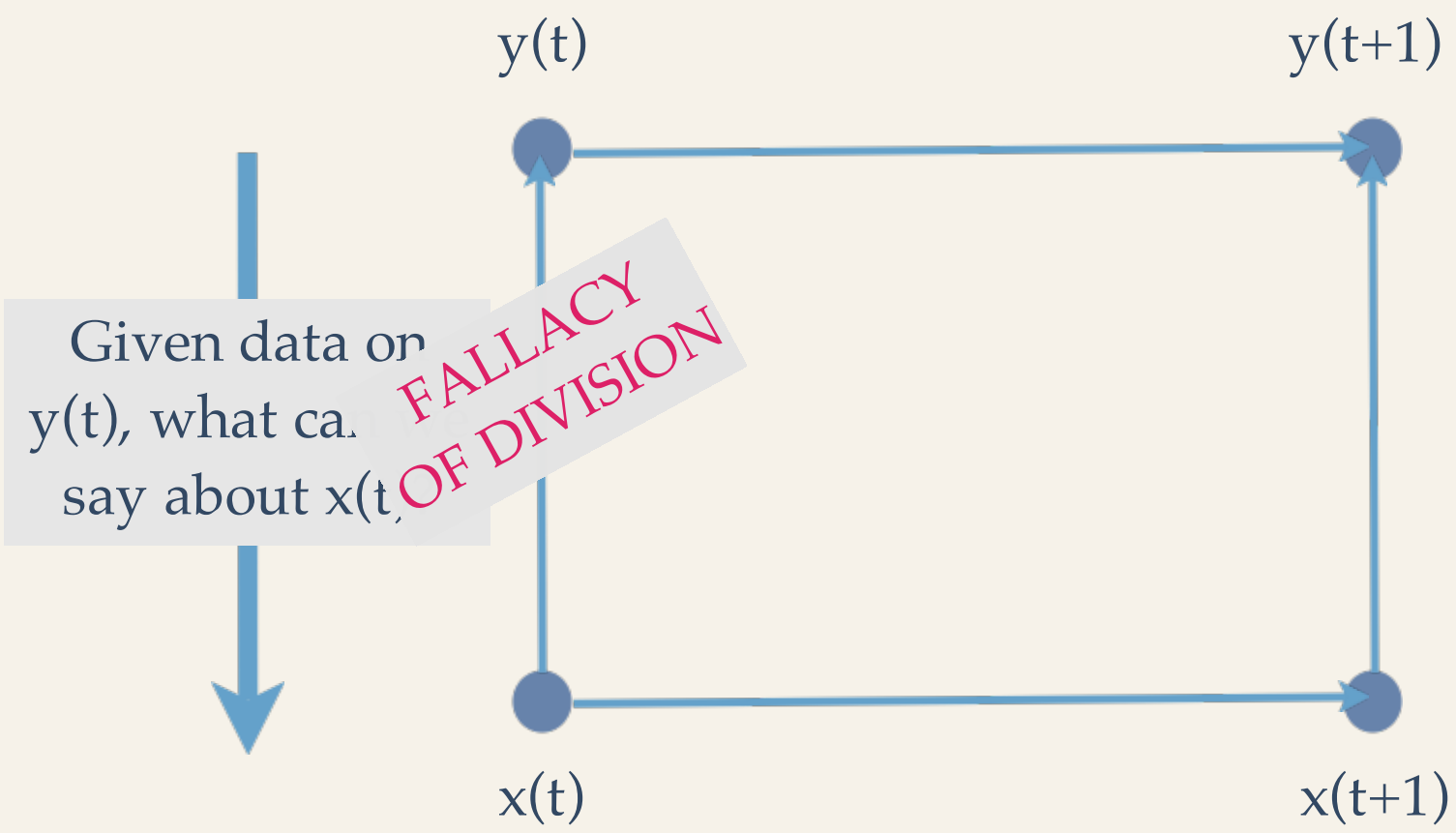

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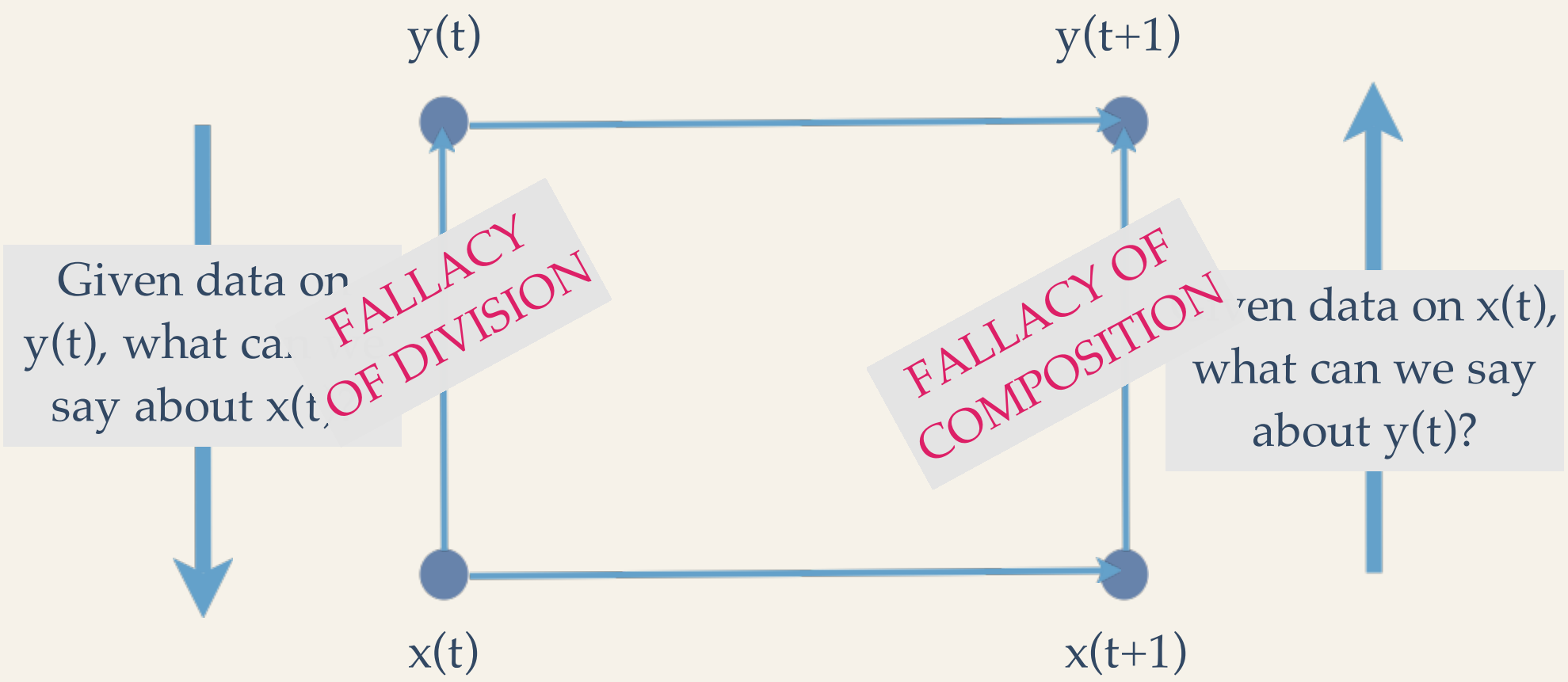
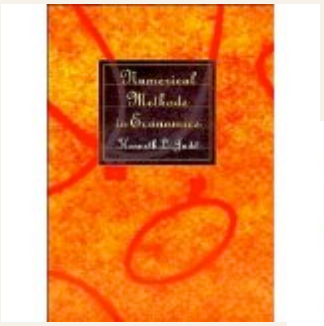
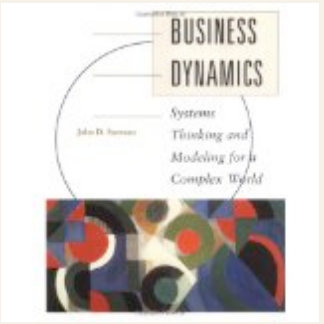
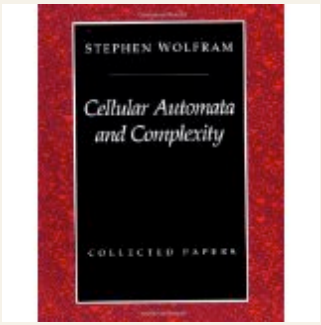


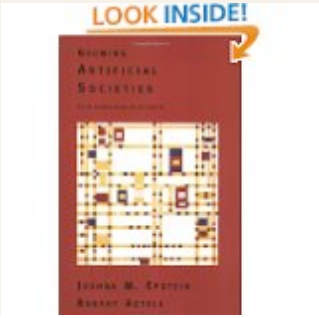
Flavors of Computational Economics

- Numerical economics
- Computational finance
- System dynamics
- Microsimulation
- Cellular automata
- Agents







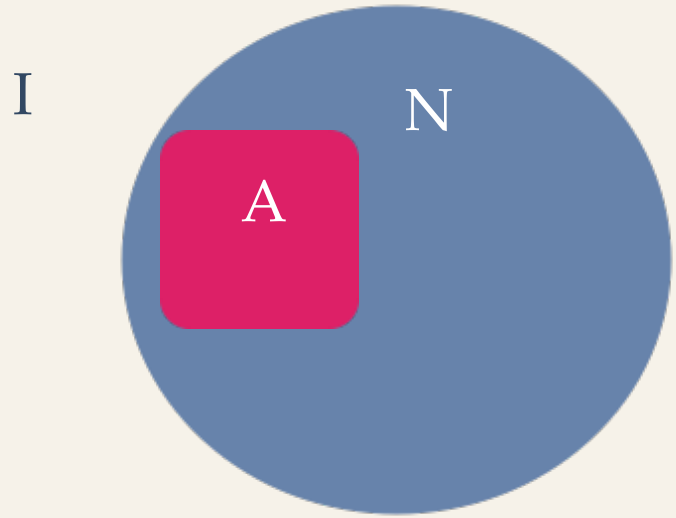


Non-Elephants in Economics

- Non-Walrasian theory of markets
- Non-Coasian theory of the firm
- Non-Nash game theory
- Non-Lucasian macro
- Non-neoclassical policy

Agentization

- Take a neoclassical model and build an agent-based version of it; What can happen?



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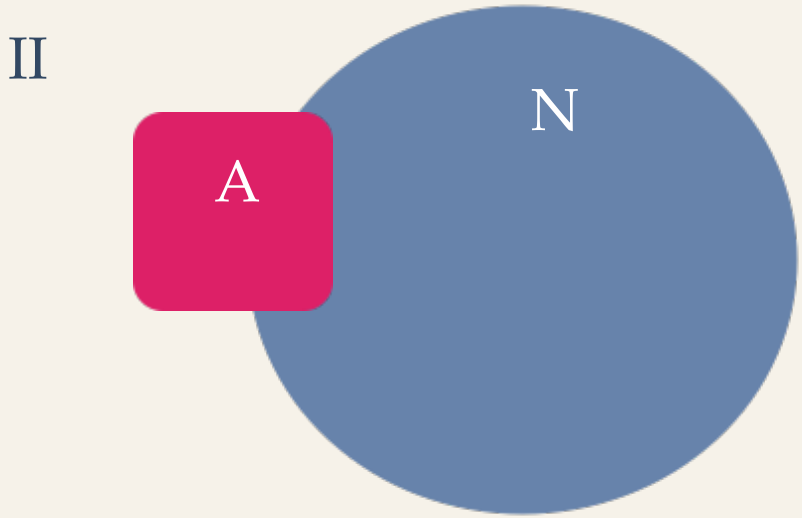

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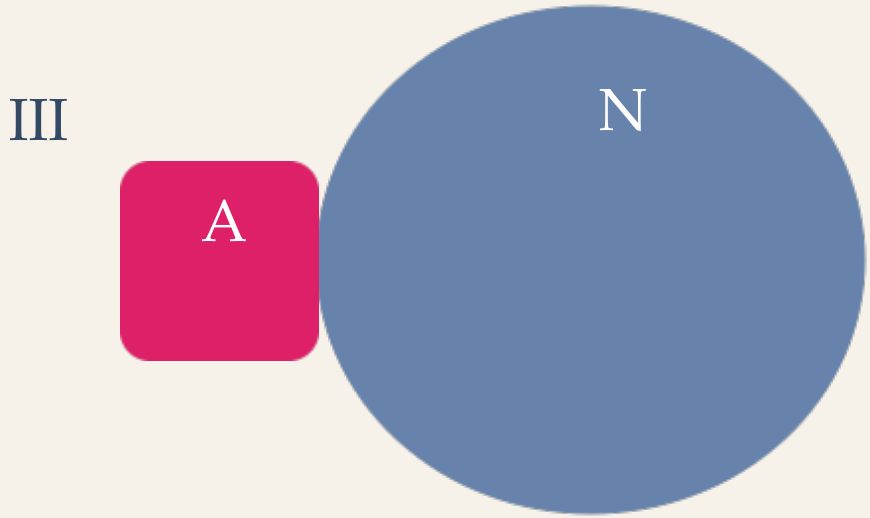
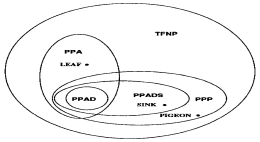


Complexity of Markets and Games

- Walras-Arrow-Debreu, Nash ≤ Brouwer
- Brouwer ≤ Sperner
- Sperner ∈ PPAD
- *k*-lateral exchange ∈P
- If there is a fast algorithm to compute Walrasian equilibria then FP = FNP => P = NP => no computer system is safe
- If P ≠ NP then Walrasian equilibria are computationally incredible

A small corner of the 'complexity zoo'



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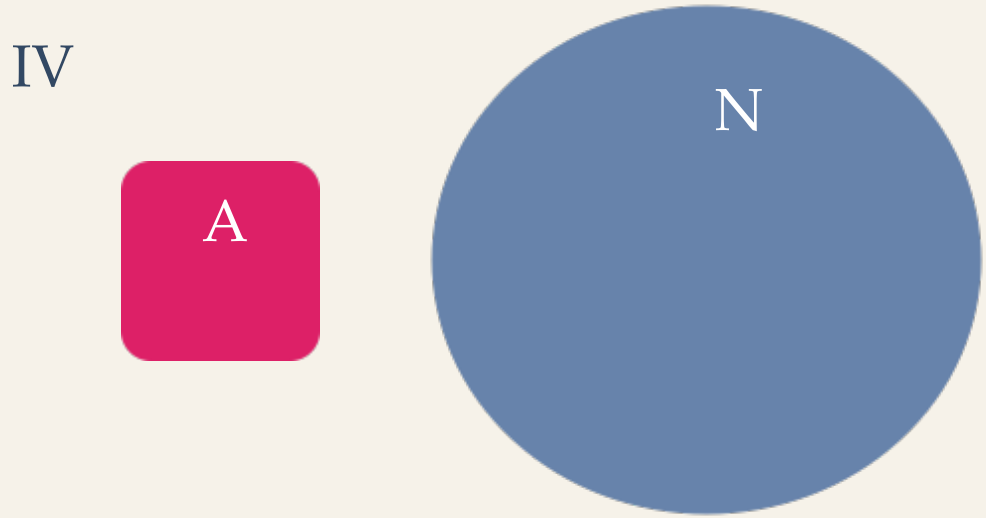

Agentization

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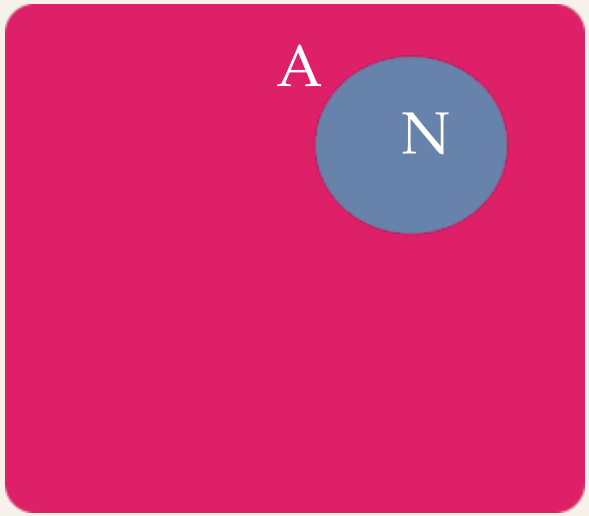
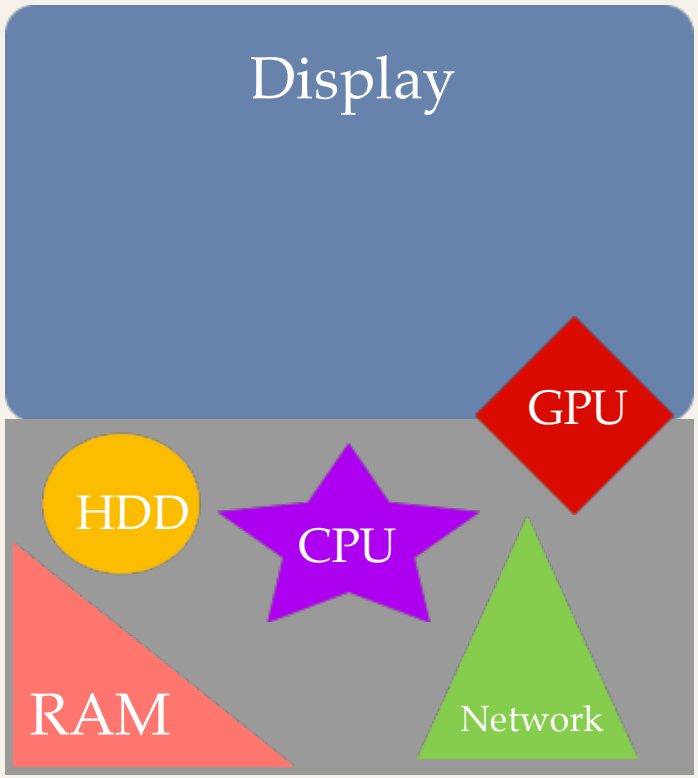
V



Computational Economics: Only Agents use the Whole Machine



Econometrics: HDD + CPU
Theory: CPU?
Applied micro: HDD + CPU
Microsimulation: network + CPU
Agents: all RAM, all CPUs, GPU, HDD, display, network

3 and 1/2 Policy Successes

- Traffic
- Epidemiology
- Combat
- Finance

Sociology of Science, I: Game Theory, Experimental Economics, Agents…

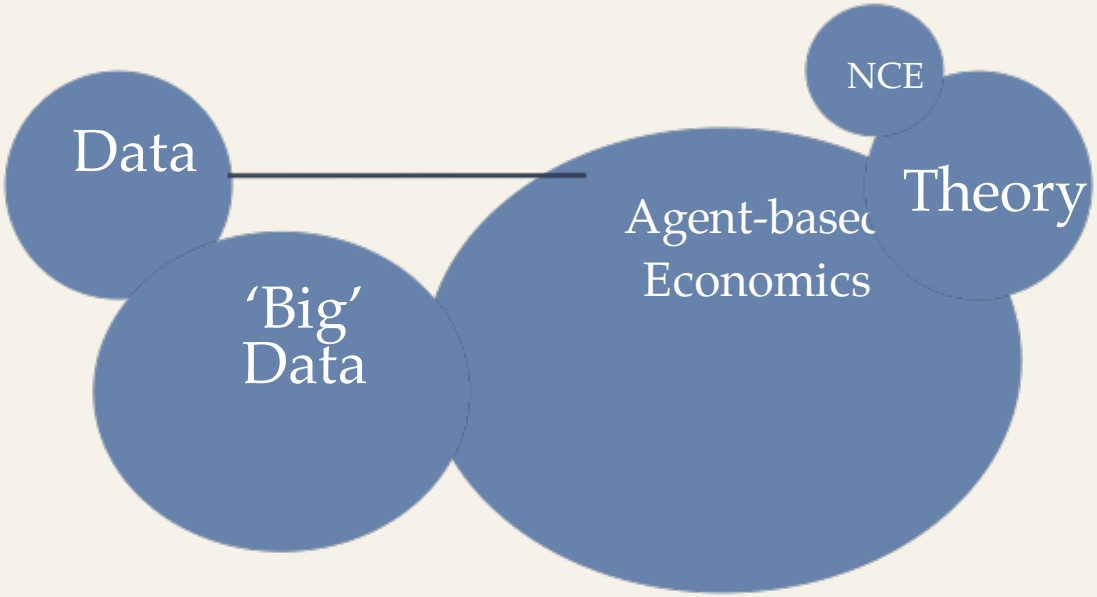
- Early *game theorists* (e.g., Nash, Shapley, Shubik, Aumann) mostly took jobs in mathematics departments ('50s forward)
  - Even by the '70s little improved (e.g., Peyton Young)
  - 'Killer app' for game theory was industrial organization ('80s)
  - Nobel for Nash, Harsanyi and Selton in 1994
- Early *experimental economists* (e.g., Smith, Plott, Roth) were similarly on the fringe of the economics mainstream ('50s - '80s)
  - Behavioral + experimental papers today appear in major journals
  - Some big departments still do *not* have significant lab facilities
  - Nobel for Smith (and Kahneman) in 2002
- Agent models today face comparable barriers…

Sociology II: Why are there so many theorems in top economics journals?

- By analogy, *Journal of Fluid Mechanics:*
  - 1950s: ~70+% of papers analytical, many have theorems
  - 1980s: <50% analytical, ~25% computational
  - today: all either computational or mixed experimental + comp.
- *American Economic Review:*
  - 1950s: >50% of papers empirical (not experimental), no theorems
  - 1980s: >50% of papers analytical, minority have theorems
  - today: >50% of papers have theorems, lemmas, formal claims; only computational results are econometric with occasional microsimulation

Economics: Computational evolution

Economics: Future?



Barriers and Bottlenecks

- Realization of large-scale models:
  - Multi-machine parallelization generically does not work
  - GPU technology is synchronous, which is problematical...
- Identifying models with micro-data:
  - 'Estimation by simulation' but function evaluation is expensive
  - Many sets of parameters may give comparable results
  - 'Manski critique'
- Need new publication 'technologies: from movies to executable papers...