

Adaptive Agents, Health Information, and Complexity

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Outline

- Observations: *Parallels* between the overall economy and the health industry
- Theory: The economy as a *complex adaptive system*
- Information:
 - Behavior
 - Self-Governance
 - Tipping points
 - Policy

Terminology

- ◆ **Complexity speak:**
 - ◆ ‘Emergence’—Macro/aggregate-structure arises from interactions at micro/agent level
 - ◆ ‘Agent-based modeling’ aka Multi-Agent Systems (computer science)— System of interacting software *objects*, each object having a well-defined sense of self-interest (aka *agent*)
 - ◆ Perpetual adaptation at the agent level
 - ◆ Stationarity at the macro level
 - ◆ ‘Self-governance’—analogous to ‘self-organization’ and ‘spontaneous order’ in which a population of agents governs itself
- ◆ ‘Institution’—a social norm or convention

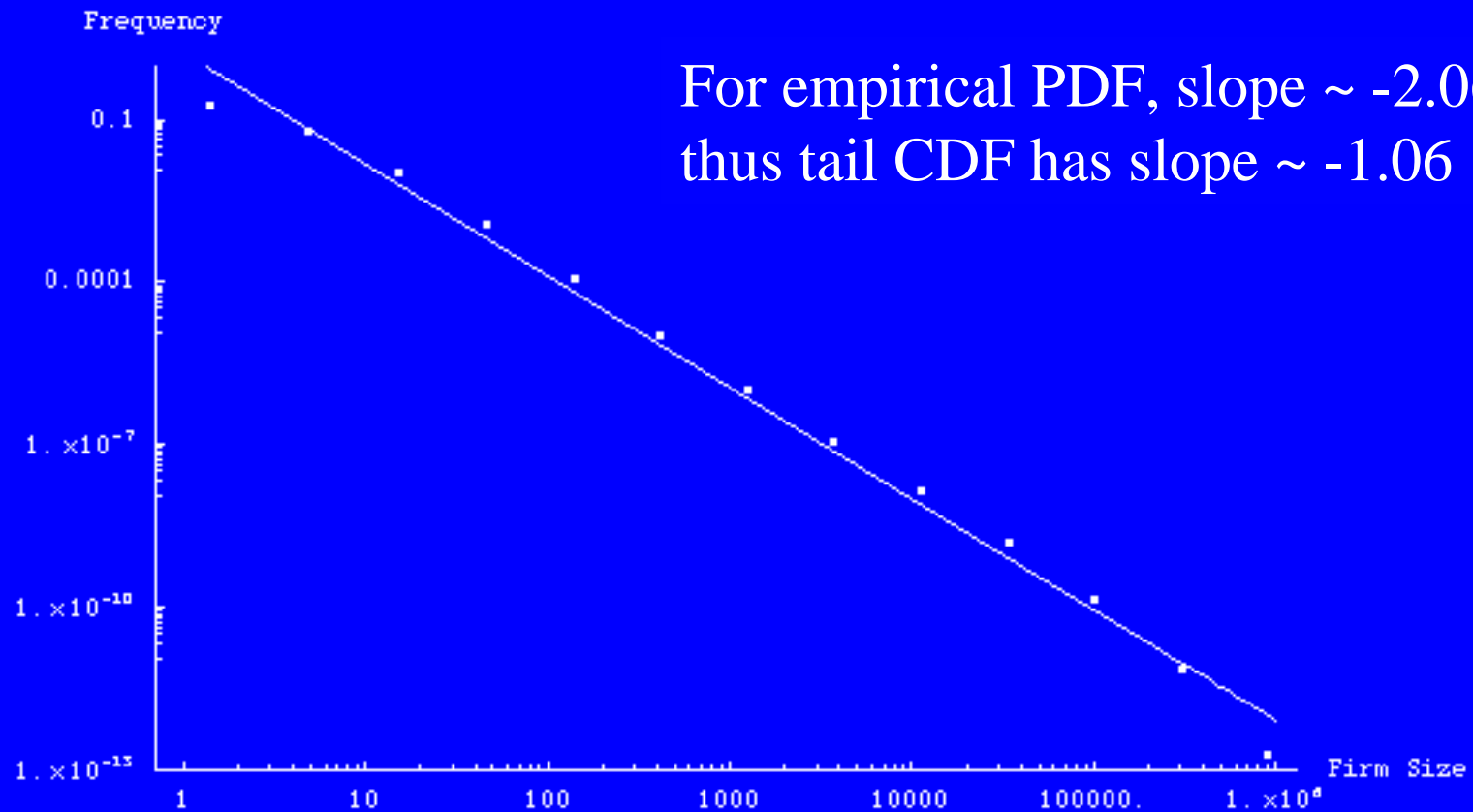
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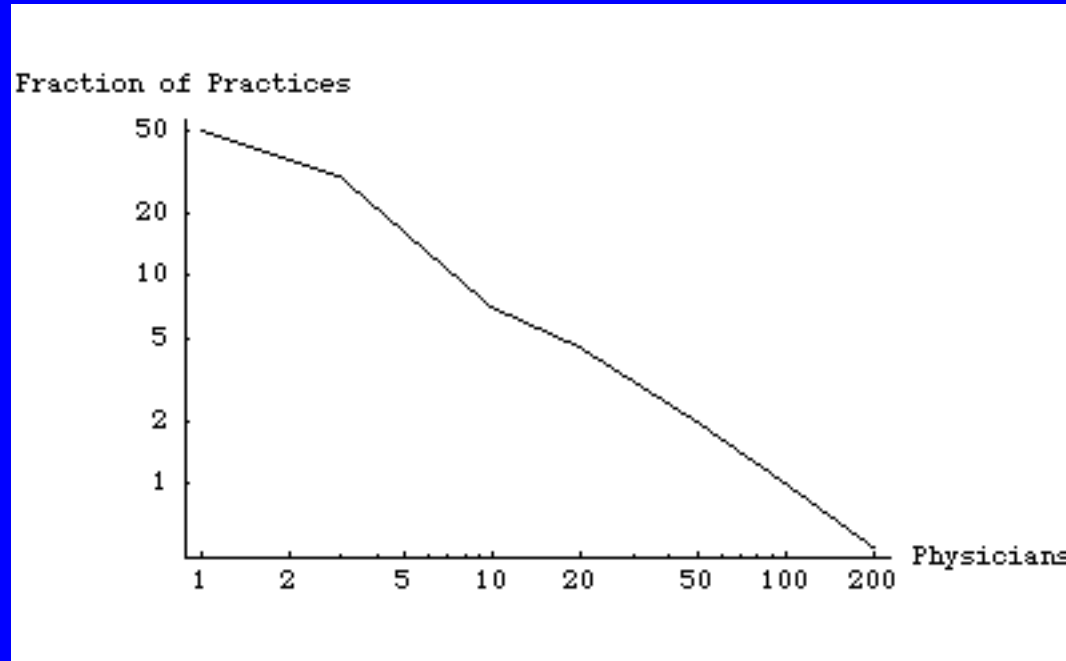
Observation 1

**System 'Scale':
Skew Size Distributions**

“U.S. Firm Sizes are Zipf Distributed,” RL Axtell, *Science*, 293 (Sept 7, 2001), pp. 1818-20



Physician Practice Size Distribution



Implications

- **Call $f(s)$ the probability density of practice size**
 - $F(s)$ is the cumulative distribution of practice size
 - For $f(s) \propto s^{-2}$, $F(s) \propto s^{-1}$
- **Same number of workers in each *decade* of size**
 - As many workers in firms of size 1-10 as in size $10^5 - 10^6$
 - As many doctors in the smallest practices as in the largest
- **Policies for largest firms usually *don't* work for smallest firms (thus the Small Business Admin.)**
- **Systems need to be tailored to firm size**
 - 1 employee firms don't need SAP

Observation 2

Handling of Sensitive Data

Firm Size Data from Tax Returns

- **19th Century:** Collect firm data by *visiting* firms
- **20th Century:** Use data on *publicly traded firms*
- **21st Century:**
 - In 2000, the IRS's Business Master File was unified onto one machine *for the first time* (in Detroit, 1997 tax year)
 - Census has access to these data for research purposes
 - Researchers have access to
 - » Census data portals
 - » Census experts who can run custom analyses
 - Researchers *do not* have access to the data!!!
 - Not a security or privacy issue!
 - Local control of data, global summaries/digest available
 - Micro-data are *revolutionizing* our understanding of industrial organization

Analogy to Health Information

- **19th Century:** Patient information stored in local physician's *head*
- **20th Century:** Patient records in *paper* format
- **21st Century:** *Electronic* information
 - How sensitive is health information?
 - Like tax records?
 - » Individual Master File not coming online anytime soon!
 - Like banking information?
 - » Access can be granted through trusted parties
 - Like credit information?
 - » Low cost (nearly free) access

Observation 3

Banking or Finance?

Reported vs Generated Information

- ‘Customer’ information a prominent feature of banking, finance and health care industries
- Banking information is simply data about customer *activity*
- Finance information is a combination of data
 - Customer *activity*
 - Current *market* activity relevant to the customer
- Health information is also a combination
 - Patient *history*
 - *Current* information generated by the health care system
- Finance *not* banking as proper analogy

Finance Information

- **Customer portfolio information**
 - *Status* information readily available to owner in environment of privacy and security
 - *History* information available with some finite window
 - *Shared* with institutions having statutory permission
- **Market information**
 - Some archaic/archival information available for *free*
 - Actionable (real-time) information is *costly*
 - » Bloomberg, First Call, etc.
 - Complete information is *very costly*
- **Interaction of customer portfolio with market is *not available* to non-owners**
- ***Inter-firm* inter-operability yet highly customized *intra-firm* IT**

Observation 4

Linking Information and Behavior

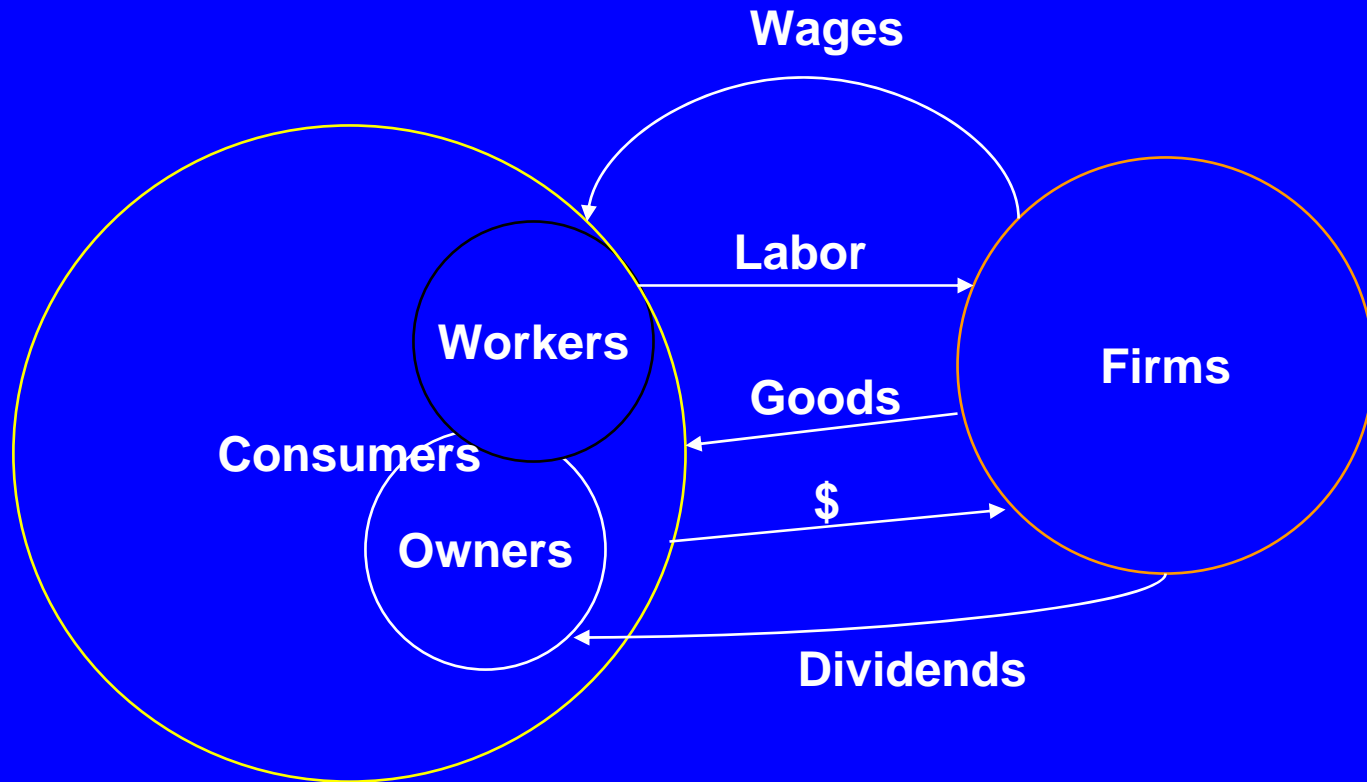
Behavioral Decision Theory

- **People do not process information objectively**
 - Violation of expected utility hypothesis
 - Gain-loss asymmetry
 - Time inconsistency
 - ...
- **Two flavors:**
 - What kinds of information corrupt are problematical
 - What information will help people make the right decisions (e.g., risk communication)
- **Behavioral finance:**
 - Markets are *irrational* in this way
 - Can you make money knowing that markets are irrational

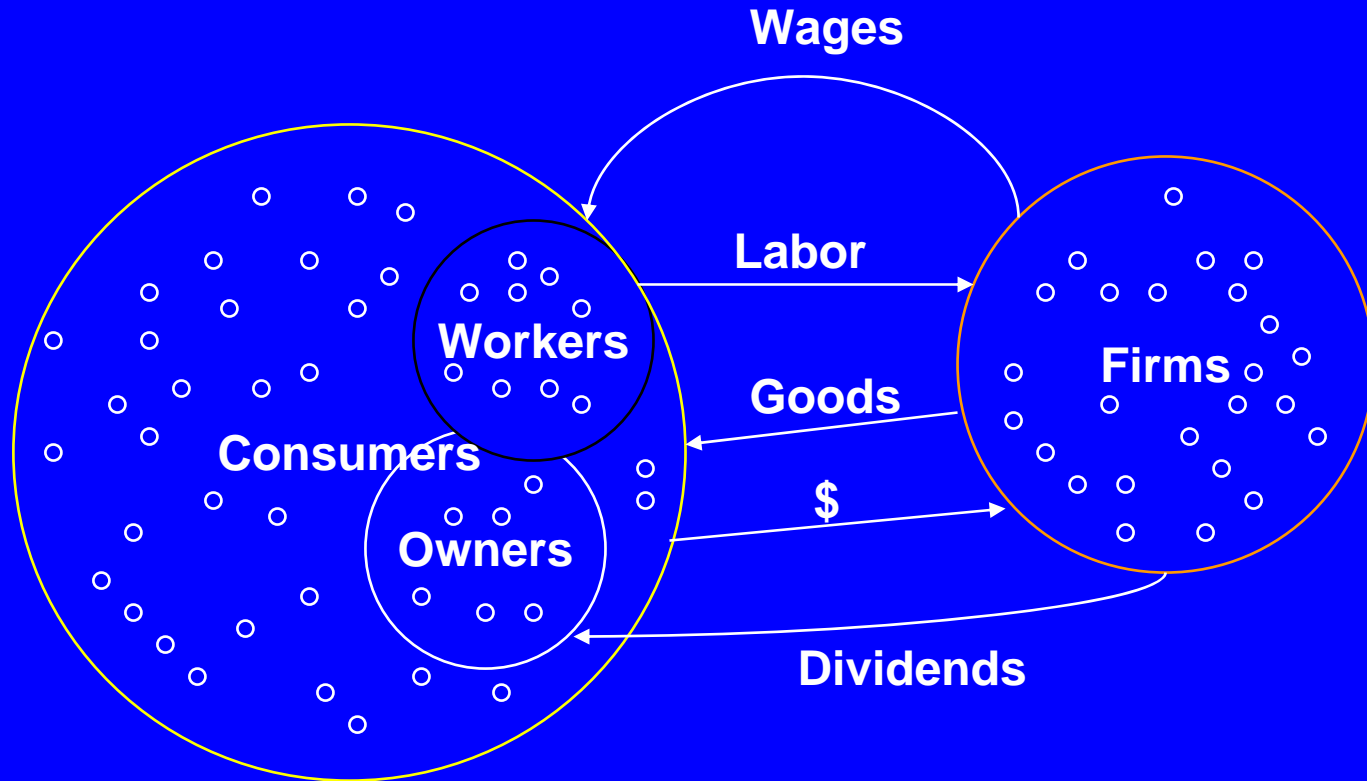
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The Economy as CAS



The Economy as CAS



Agent-Based Computing (Multi-Agent Systems Computer Science)

- **Agents:**
 - Heterogeneous
 - Boundedly rational
 - Interact directly with one another
 - Out of equilibrium interactions permitted; equilibrium agnosticism
- **‘Canonical experiment’**
 - Situate agents in environment
 - Let them interact (‘spin the model forward in time’)
 - Query the model for output/statistics that resemble the real world
 - Revise agent structure and repeat

Agent-based Traffic

- Decade ago: traffic conceptualized as fluid flow
- Large-scale models rendered as computational fluid dynamics, resolved on vector supercomputers
- Agent revolution:
 - Every vehicle an object
 - Simple driving rules sufficient
 - Emergent traffic jams
- Large-scale models of Albuquerque, Dallas-Fort Worth, Portland, all of Switzerland
- Port to pedestrian flow, emergency egress, &c.

Agent-based Combat Models

- Decade ago: combat conceptualized as fluid flow
- Large-scale models rendered as computational fluid dynamics, resolved on vector supercomputers
- Agent revolution:
 - Every soldier, every grenade, every bullet an *object*
 - Alternative 'rules of engagement,' differential success
 - Pick policy this way
- Large-scale models of various sensitive areas
- Emergence of *unintended consequences*

Agent-based Epidemiology

- **Mathematical epidemiology makes unrealistic assumptions about**
 - How people interact (e.g., uniform mixing)
 - Homogeneity of immune systems
- **Agent-based epidemiology uses heterogeneous agents in realistic interaction networks**
- **Large-scale renderings of epidemics for U.S. cities (e.g., Portland in recent *Scientific Am.*)**
- **Variety of infectious agents:**
 - Smallpox, various strains of influenza, SARS, &c.

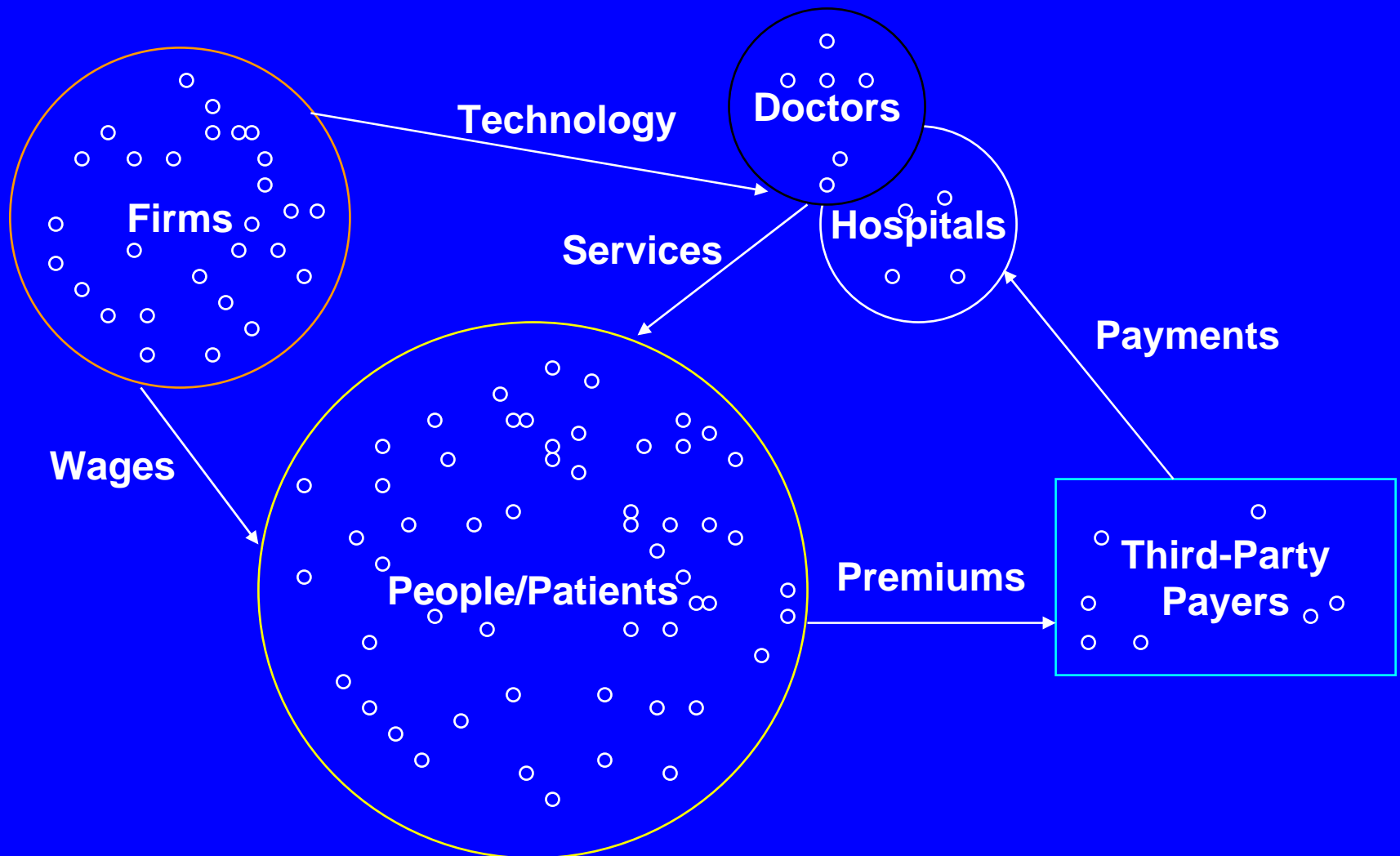
Other Public Health Applications

- **'Epidemiology' of smoking**
 - Peer effects among adolescents
 - Network data from schools
 - Contrast 'bottom up' vs. 'top down' policies
- **STD transmission dynamics**
 - Peculiar network structure for HIV
- **Social norms of medical device adoption**
 - Regional variation of cardiac care in Florida as 'local social norm'
- **Crime and social interactions**
 - Car theft more 'social' than homicide, for example

Applications to Economics

- **Artificial stock markets:**
 - Santa Fe Institute: ecologies of price predictors
 - Foreign exchange, bond markets
- **Residential segregation**
- **Firm formation models:**
 - 10^7 agents
- **Macroeconomics from the bottom up**
 - 10^8 agents
- **Sloan Foundation: Agent mode of the operation of colleges and universities**

The Health Care 'System' as CAS



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Behavior

- Information should be *liquid*...but how liquid?
 - Like credit reports, financial information, or IRS data?
- Without a model for how liquidity alters *behavior* we are guessing
- What are the economic costs and benefits?
- What are the unintended consequences?
 - Consumer anxiety over unexpressed gene?
 - Can these be mitigated through risk communication?

Governance Institutions

- **Two Extremes:**
 - Theory of the Firm: ‘privatization’
 - Theory of the State: ‘nationalization’
 - » Barbarian invasion/common defense
 - » Economic efficiency
- **Self-Governance**
 - Many long-lived examples in common property resource management (aka ‘tragedy of the commons’)
 - » Heurta irrigation (Valencia, Spain)
 - » High mountains and meadows (Torbel, Switzerland; Hirano, Nagaike and Yamanoka villages, Japan)

Institutions for Managing Common Pool Resources (CPRs) (Ostrom 1990, 1994)

- **Self-organized institutions for managing CPRs are:**
 - common
 - sometimes long-lived
 - sometimes fragile
- **Successful institutions characterized by:**
 - boundary rules determining who has access to the common
 - authority rules governing allocation
 - active forms of monitoring
 - absence of grim trigger strategies

Research Program: 'Grow' Self-Governance Institutions

- **Situate agents in an economic environment**
- **Give them some incentive to coordinate their activities**
- **Study the kinds of self-governance norms that emerge**
 - **Efficiency, equity**
 - **Stability, resilience, robustness, &c.**
- **Alter the information available to agents and repeat**

Tipping Points

- Under the *local emergence* of multiple institutions, which survive in the long run?
 - Information-rich environments promote efficiency
 - Private information environments promote innovation
 - Which kind of environment promotes equity?
- Conventional conceptualization game theoretically as coordination problem
 - Fax machine example
 - VHS vs. BetaMax
 - Today we know much about such dynamics
- Without a model, impossible to say much

Policy

- At high levels of abstraction, *definitive* policy conclusions are rare
- Policy needs to be informed by models
- Without models...
 - ...effectiveness of alternative policy regimes is guesswork
 - ...unintended consequences unknown
- Research program on health information policy would include explicit models of the incentives facing each actor in the 'system'

Summary

- **Strong analogies between health information dynamics and information flows in other economic arenas**
- **Agent-based modeling is a way to formalize the incentives facing the actors in an economic system**
- **The main point of health information is to modify behavior**
- **We should expect the emergence of local, self-governed health-information norms**
- **The evolution of these norms can only be systematically studied by models**