Applications of complex systems reasoning in economics

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Micro/Macro Fluctuations 1

- The U.S. economy is composed of about 300 million individuals, 100 million households and 25 million firms (http://quickfacts.census.gov/qfd/states/00000.html)
- In an system in which aggregate fluctuations are the sum of independent fluctuations of components, we would expect *very* smooth macroeconomic indicators

Micro/Macro Fluctuations 2

- In reality, as we know, the macroeconmy is subject to significant fluctuations which we call the business cycle
- Real GDP, employment, price levels and rates of inflation, profit rates, incomes and income distribution have business cycle components

Micro/Macro Fluctuations 3

- Statistically business cycle fluctuations reflect correlated movements of corresponding micro-level variables
- One basic puzzle of social science methodology is to explain micro correlations
- Conventional equilibrium theory relies on “external shocks”

Micro/Macro Fluctuations 4

- Conventional equilibrium theory sees all fluctuations as giving rise to appropriate negative feedback signals through market-clearing prices
- As a result conventional equilibrium systems, though they are adaptive and have many degrees of freedom, are not complex systems in the usual sense

Micro/Macro Fluctuations 5

- The commodity form of productive organization does give rise to stabilizing negative feedback through price signals
- If markets are not "complete", the system as a whole will exhibit the characteristic mixture of positive and negative feedbacks of complexity

Emergent properties 1

- An important second clue to complex phenomena in economies is the statistics of distributions of wealth and income
- The original discovery of scaling or power laws characteristic of many complex systems was due to Pareto's research on wealth distributions

Emergent properties 2

- Conventional equilibrium theory takes the original ownership distribution of productive resources (land, labor, and capital) as exogenous
- This means either that it is determined arbitrarily outside the system, or that some random process determines ownership distribution

Emergent properties 3

- It is thus very hard to rationalize the statistical regularities of income and wealth distributions within the framework of equilibrium theory
- But these statistical regularities persist
- Statistical self-organization in scaling distributions is a common characteristic of complex systems

Emergent properties 4

- There seem to be two self-organizing processes in income and wealth
- Earned income (employee compensation) has an exponential form
- Property income (profits, interest, rent) has a power-law form

Emergent properties 5

- Both exponential and power-law distributions are maximum-entropy distributions
- Exponential distributions arise from an additive constraint on the mean
- Power-law distributions arise from a multiplicative constraint on the logarithm of the mean

Emergent properties 6

- These components of income and wealth distributions reflect the classical distinction between labor mobility tending to equalize levels of wages (additive) and capital mobility tending to equalize profit rates (multiplicative)

Long-distance correlations 1

- Complex systems exhibit a slow decay of autocorrelation functions in space and time
- Shocks to one part of the system propagate with low decay rates throughout the system
- The "butterfly effect" is a dramatic example of this phenomenon

Long-distance correlations 2

- Slowly decaying autocorrelations lead to unexpected macro-level causal chains and to unpredictable time series behavior in economic data
- An example of macro links is the complex supply network linking U.S. markets with Chinese and other suppliers

Long-distance correlations 3

- Growing financial fragility is another manifestation of these slowly decaying correlations
- Increases in leverage in one part of the financial system propagate through the system, changing its stability
- Sudden crises in liquidity and credit erupt unpredictably

Heavy tails 1

- Weak decay of autocorrelations also offers a promising explanation of the heavy tails in distributions of price and output fluctuations
- Conventional statistical methods tend to assume Gaussian distributions which predict a very rapid decay of probability with size of fluctuation

Heavy tails 2

- The premise on which Gaussian probability rests is that fluctuations are the sum of a large number of weakly correlated shocks
- When autocorrelations decay slowly, shocks become significantly correlated
- Thus large fluctuations are more probable

Heavy tails 3

- The crisis of conventional economic equilibrium theory is also a crisis of econometrics
- The presumptions of equilibrium theory (external, damped shocks) dovetail with the axioms of econometrics (Gaussian disturbances) to make the economy seem simpler and more stable than it is

Heavy tails 4

- The complex systems vision of the economic system warns against this error, but does not offer an easy remedy
- There are no general theorems on slowly decaying correlations as widely applicable as the central limit theorem

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Regime change 1

- Conventional economic equilibrium theory reasons from the axiom of complete and liquid markets
- Under these assumptions, market dynamics are qualitatively homogeneous despite fluctuations
- Real-world dynamics exhibit striking inhomogeneities over long time scales

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Regime change 2

- In “normal” periods the overnight market for Federal Funds (bank reserves) clears at a relatively high nominal interest rate
- Adjustment of the supply of reserves promptly and predictably moves the Federal Funds rate

Regime change 3

- But in “crisis” periods when financial institutions hoard reserves there is a qualitative change in this market to “liquidity trap” dynamics
- The Federal Funds market produces an interest rate barely above zero
- The provision of more reserves has practically no impact

Regime change 4

- Regime changes of this kind are met with frequently in complex systems
- The system evolves with some relatively stable dynamics for a possibly long period and then endogenously undergoes a phase transition to a qualitatively different type of dynamics

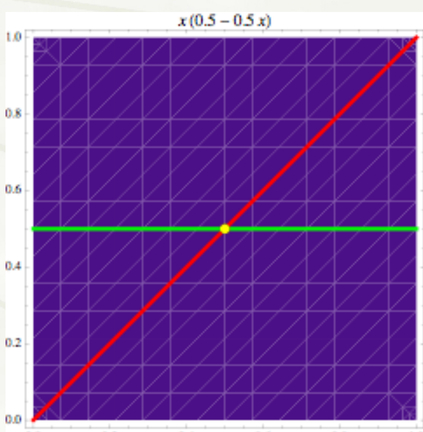
Coordination equilibria 1

- The complex dynamics of the macro-economy arise from social interactions that are not completely mediated by the market
- Examples include the instability of credit provision, and the dynamics of spending and aggregate demand

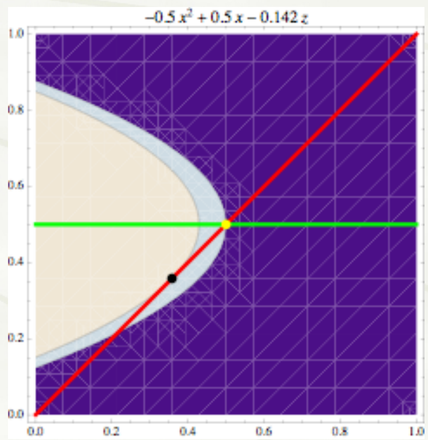
Coordination equilibria 2

- A simple model for coordination problems makes the decision of each agent, *x*, depend on the average decision of all the (identical) agents, <*x*>
- This is similar to the *mean-field approximation* that simplifies complex systems analysis

Without externalities equilibrium is unique



With linear externalities equilibrium is inefficient



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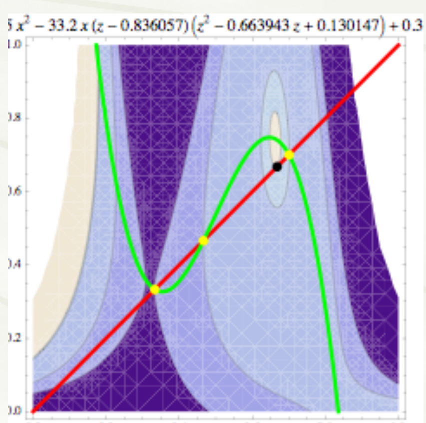
With nonlinear externalities equilibrium can be unstable



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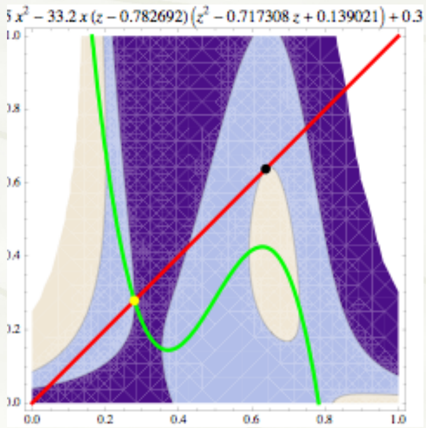
Equilibria can disappear in a catastrophe



Nonstationary paths of technical change

- Complex systems generate non-stationary statistical paths, in contrast to Gaussian perturbation systems
- Economic technical change is irreversible and path-dependent, giving rise to nonstationary statistics

Complexity in social and physical systems 1

- Many of the insights we get from studying complex physical systems shed light on puzzles in social and economic systems
- Much of this illumination simply sweeps away cobwebs created by presumptions that systems have unique, stable equilibria

Complexity in social and physical systems 2

- Once we are prepared to acknowledge the economy (and more broadly society) as a complex, adaptive system far from equilibrium many phenomena, from crises to unexpected patterns of long-run technical change, become qualitatively understandable

Complexity in social and physical systems 3

- In complex biological and physical systems the main shaping force over time is evolutionary selection
- The system tends to explore all the degrees of freedom available to it
- Those that are self-limiting disappear; those that are self-reinforcing survive

Complexity in social and physical systems 4

- In human social systems there is an additional level of complexity: the intentional and purposeful behavior of human beings
- During the 18th century Enlightenment it became a cliche to note the importance of “unintended consequences” of human action

Complexity in social and physical systems 5

- The fact that human intentions are never realized, however, does not mean they can be neglected in social science reasoning
- We have legal systems not just from evolutionary selection, but because people have an abstract idea of justice they seek to institutionalize

Complexity in social and physical systems 6

- Complex economic systems like energy generation and distribution, transportation, financial services combine planning with blind selection
- The human individual is a paradigmatic complex system; human society is the interaction of an enormous number of human individuals