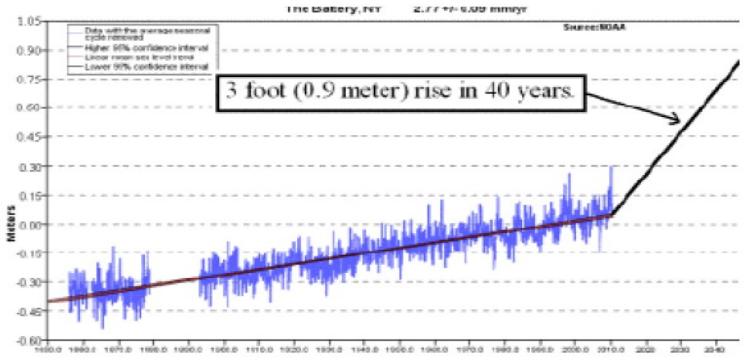
Lecture 1: DISCONTINUOUS CHANGE AND HOW WE STUDY IT

Discontinuous change is a sharp (but *fuzzy*) change that occurs in short period of time that affects us in major ways, as opposed to the marginal changes in prices and quantities. The sharp short period of change differentiates models of discontinuous change from equilibrium efficient market-clearing models that underlie much of standard economics and "Great Moderation" etc that supposedly dominated macro-economies. Discontinuous changes are often associated with **tipping points** – a point at which a modest change in a variable sets of much larger changes in it or in some other variable, which makes it hard to restore the earlier levels of those variables. increases or decreases. Examples illustrate the discontinuous phenomenon:

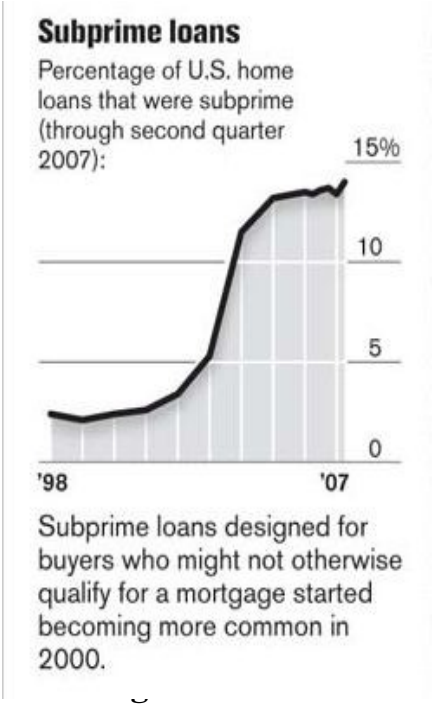
2 The Sky is Falling: the deadly threat posed by Near Earth Objects and what we can do about it (former Rep. Dana Rohrabacher) - On June 14, 2002, the Earth narrowly avoided a deadly event.... which quite possibly would have had a devastating effect on the course of humankind. … a football field sized asteroid careening at 6.2 miles per second came within 75,000 miles of hitting the Earth. Three days later the asteroid was discovered, but of course by then it was far too late. Had the asteroid hit the Earth, the devastation may have equaled the 1908 Tunguska event, an asteroid or comet that flattened over 80 million trees in a remote region of Siberia. See http://neo.jpl.nasa.gov/risk/

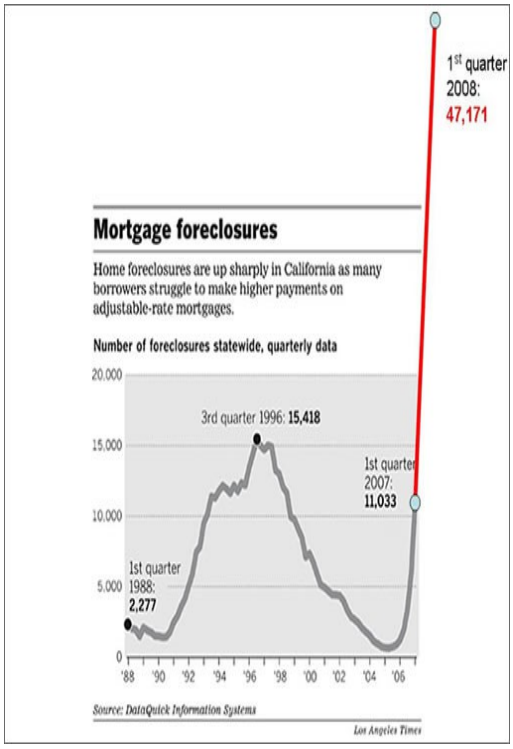
NASA, June 29, 2017: We should be concerned about the possibility of an asteroid impact, but not overly worried. The chances of a large NEO heading toward the Earth are very small, but the consequences of a collision could be very large. In the worst case, we could have an impact that leads to a global catastrophe, but that would take an asteroid larger than about 1km in size. The NASA program has already found over 90 percent of those objects, and because we track them very closely, we know that none of them can impact the Earth over the next few years.

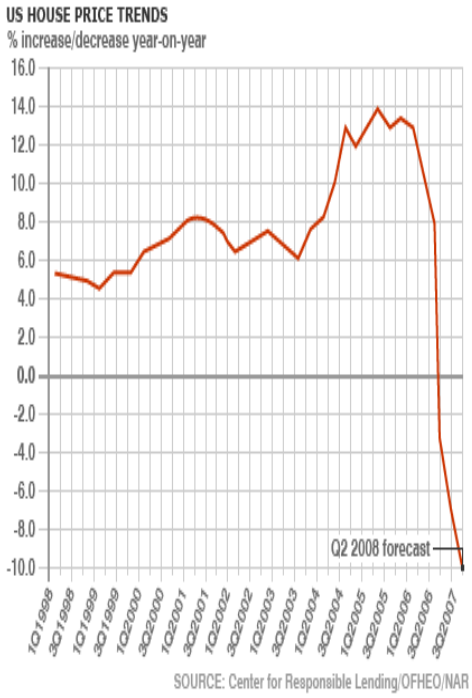


National Research Council (2002): Abrupt Climate Change occurs when the climate system is forced to cross some **threshold**, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause. Chaotic processes … may allow the cause of such an abrupt climate change to be undetectably small …"**an abrupt change is one that takes place so rapidly and unexpectedly that human or natural system have difficulty adapting to it."** – tipping point, phase transition.

3. Achilles Heel/Squeaky Wheel of Capitalism – Banking system, Housing Market bubbles.



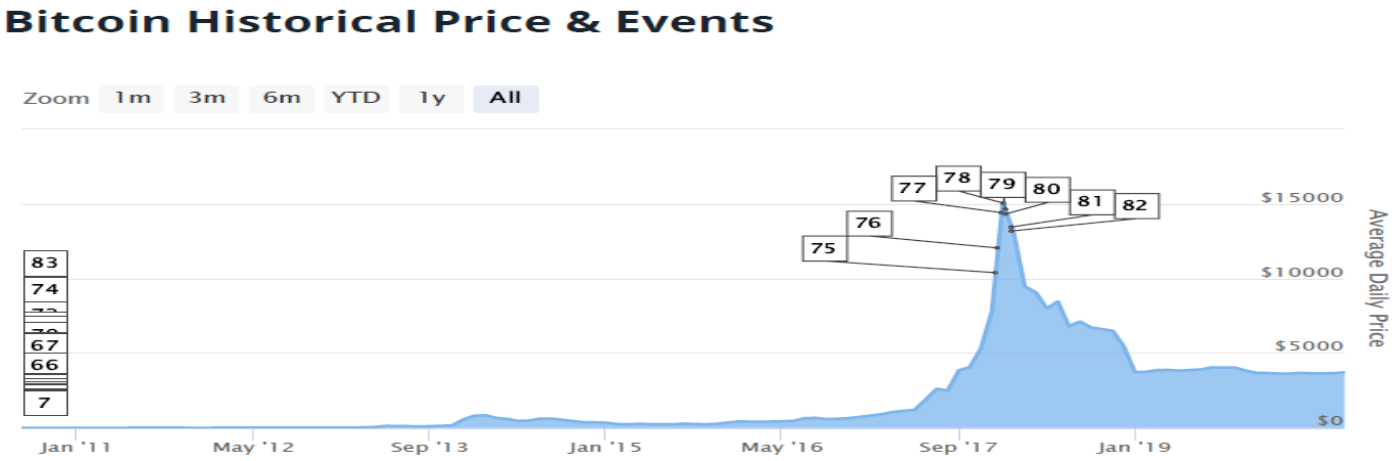




Financial implosion →

Post GR how much have we built in barriers to future speculative runs, bubbles, disasters/ weakened those barriers?

4. Bitcoin



CBOE Bitcoin Futures are launched - December 11, 2017

Bitcoin value: $14594.78 Bitcoin value **10 days** later: $17010.53 View Event #75 on Chart

Futures on the world's most popular cryptocurrency surged as much as 26 percent from the opening price in their debut session on Cboe Global Markets Inc.'s exchange, triggering two temporary trading halts designed to calm the market.

CoinMarketCap drops South Korea prices from cryptocurrency rates and regulator inspects cryptocurrency bank accounts. - January 8, 2018

Bitcoin value: $16831.09 Bitcoin value **10 days** later: $10685.16 View Event #79 on Chart

CoinMarketCap removed prices from South Korean exchanges from its calculations of cryptocurrency rates without any warning, resulting in a steep drop in all prices. Additionally, Korea's financial authorities on Jan. 8 launched an investigation into cryptocurrency-related services provided by local banks amid criticism that recent government measures are having little impact on cooling the markets.

How should you link the historical events to the changes in prices? Great paper for class.

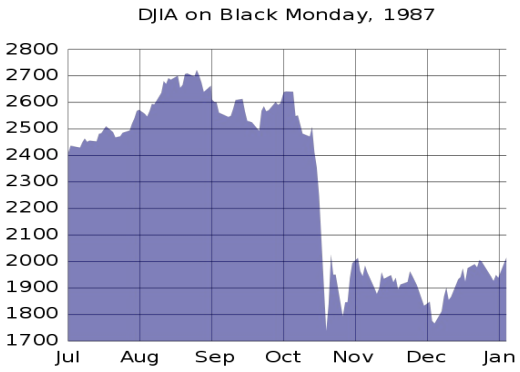
Bitcoin Cash hard fork - November 15, 2018

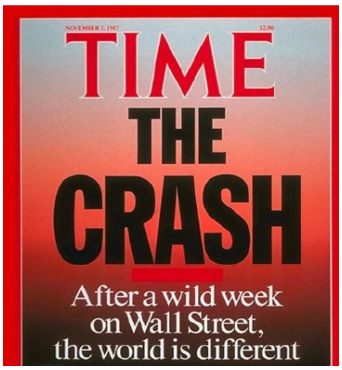
Bitcoin value: $6130.99 Bitcoin value **10 days** later: $4275.09 View Event #102 on Chart

In November 2018, a hard-fork chain split of Bitcoin Cash occurred between two rival factions called Bitcoin ABC and Bitcoin SV. This caused a decline in prices across the cryptocurrencies due to uncertainty.

But **not all discontinuous financial changes → economic disasters.** Some financial disasters have little impact.

On October 19, 1987, Black Monday the Dow Jones fell from 2246 to 1738. The drop was 34 SDs off the normal variation in market prices. (From Economist, Oct 2012: TWENTY-FIVE years ago, on October 19th 1987, global stock markets suddenly, and unexpectedly, collapsed on what instantly became known as Black Monday. The Dow Jones Industrial Average fell by almost 23% in a single session, still a record decline.... Parallels with the 1929 crash, which preceded the Great Depression, were immediately made.





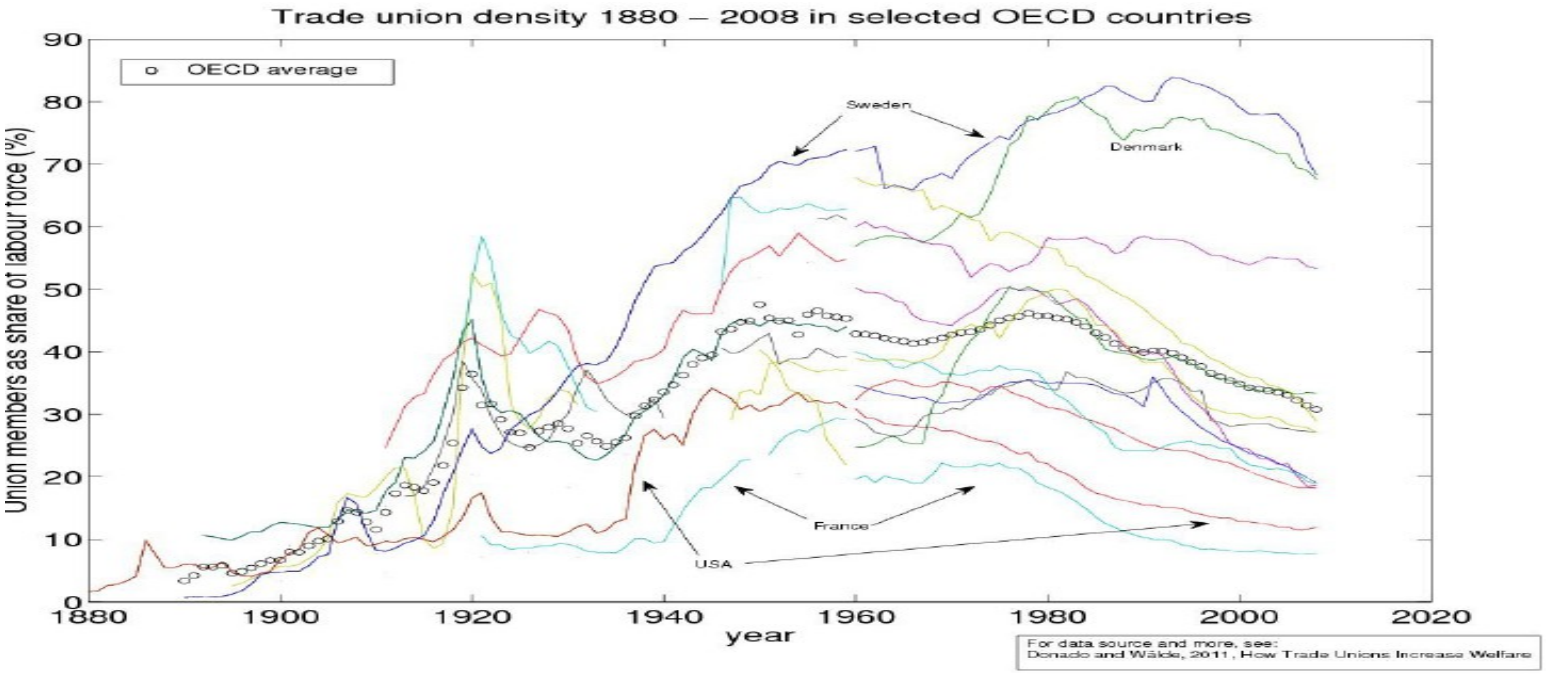
In fact, financial crises that erupt regularly Sweden 1992, East Asian 1997, Mexico 1994 Russia 1998. Some turn into complete disaster, some just are unpleasant hiccups. **A PAPER TRYING TO DETERMINE WHY?**

5. DISCONTINUOUS CHANGES IN INSTITUTIONS : Sudden surprising collapse of the Soviet Union (aka Evil Empire) between 1988 and 1991. Empire dissolves in 1989; USSR in 1991.

Few predicted collapse of communism but see Timur Kuran reading. Many believed Soviet system would converge gradually toward ours and that when ex-Soviet became market-oriented, it would produce immediate economic boost. In fact most transition economies suffered 20%-30% losses before began to recover while China did better with gradual changes. Other examples of **discontinuous regime change:** South Africa. Shah in Iran ... Suharto dictatorship in Indonesia. The collapse of Mayan society. Joseph Tainter's The Collapse of Complex Societies gives examples of discontinuous societal changes Arab Spring revolutions. Korean 2016-17 candlelight revolution. Trump election? How much of Chinese domestic policies based on fear of Soviet style collapse?

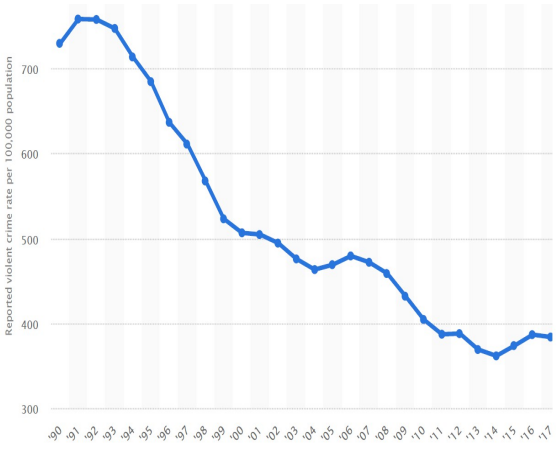
UNION SPURT In 1930s. After Great Depression unions seemed dead as doornails. AEA President George Barnett, declared: "American trade unionism is slowly being limited in influence by changes which destroy the basis on which it is erected. ... I seen no reason to believe that American trade unionism will ... become in the next decade a more potent social influence." From mid-1930s to mid-1940s, unions grew massively. In the 1960s essentially no public sector workers were union; in a decade unionization jumped to 35-40%. **Growth spurts of** unionism occurs in other countries and for other social movements – living wage, anti sweatshop activity (ie 1995, few living wage campaigns; from 1995-present, over 100) – Occupy Wall Street. This cries out for a universal explanation.

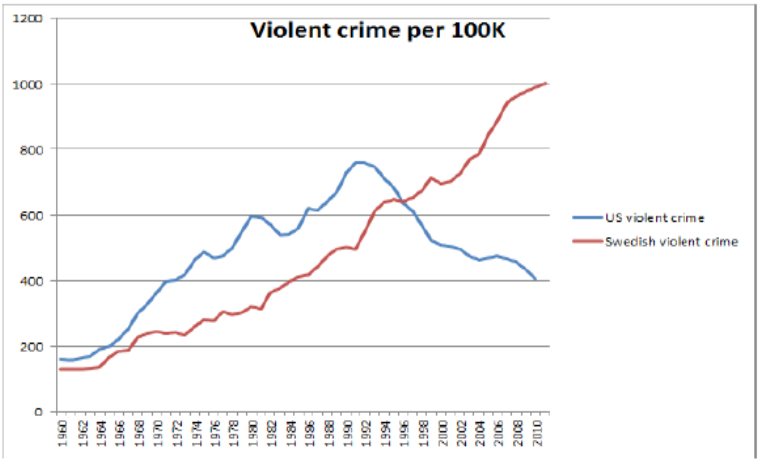
6. Crime/Social Pathologies – discontinuities among cities. Some US cities had social disaster areas, which seemed incurable a few years ago: half a million homeless; crime rates rising from 1960s; children are brought up in fatherless homes with incomes below the poverty rate. Problems concentrated among blacks, but level of single parent families among blacks that shocked Moynihan in 1963 is the now level among whites Wm Julius Wilson explains urban social pathologies in terms of the interconnections among migration, role models, and economics.



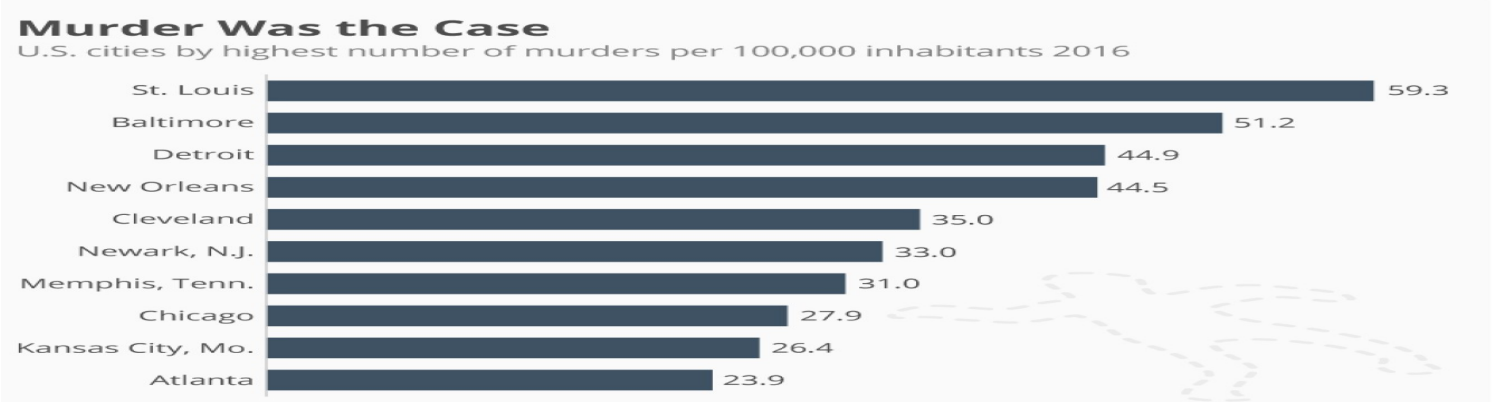
Much to the surprise of most analysts, some problems – such as the rate of crime – with Jessica Wolpaw Reyes (QJE) evidnece that LEAD effects that identifies drop in lead from cars 10-15 years earlier as main factor.

US VIOLENT CRIME, 1990-2018,



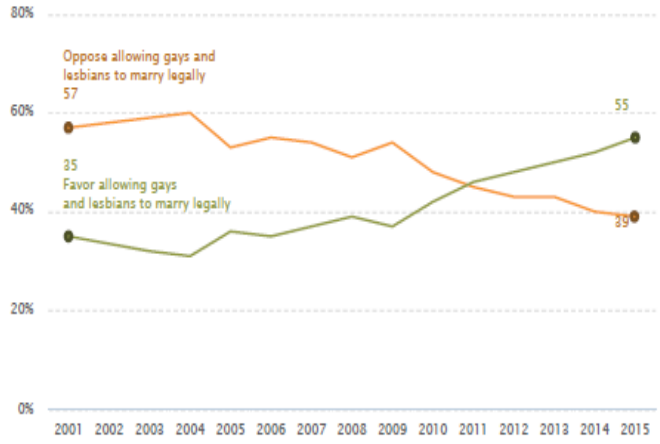


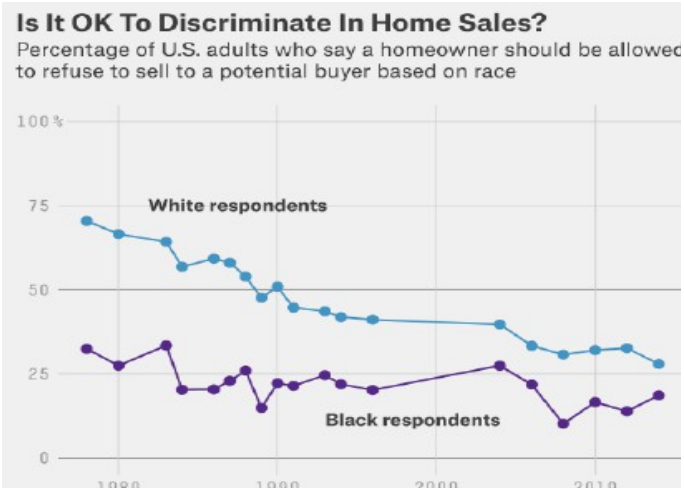
But bigger discontinuous pattern is found across cities



Where is? Boston 7/100,000; ; NY 4/100,000 Washington DC 17/100,000 http://www.neighborhoodscout.com/

Gradual or discontinuous change in attitudes – gradual yearly cumulation → discontinuous over two decades





But rise of rascist violence and social media attacks. How discontinuous are these patterns?

HOW TO ANALYZE BIG CHANGES

Standard marginal economics is *ceteris paribus* analysis of small changes around equilibrium in prices, quantities, regulations, usually in linear model, whereas discontinuities involve non-linearities. Models of individual maximization treat one agent independent of others, assuming individual has a smooth single peaked maximand with optimum that you find by differentiating/hill-climbing. Market models shift one schedule and do comparative statics, stabilizing through negative feedback loops. **Big changes destabilize through positive feedback loops**.

Experimental psychology/behavioral economics identify behavior that deviates from rational optimizing responses to incentives/information/etc but not big changes.

Why big changes are hard to analyze:

1)THEY ARE EXTREME AND RARE SO NOT MANY OBSERVATIONS. How do you learn and generalize from a few examples? What is the counter-factual to a rare event?

2)LOTS OF THINGS HAPPEN AT ONCE. The opposite of ceterus paribus is *mutatis mutandis*, which refers to all the changes that happen in a legal transaction. I use it to refer to feedback loops and interactions, income effects as well as substitution effects – a true dynamic general equilibrium.

Not only how you respond to price changes but your neighbor responds to your response and you respond to how your neighbor responds to your response → run on bank, bubbles, riot in street. If you want to know how society responds to "Obamacare" need to know how lots of players – Congress, judiciary, political parties, state governments, insurance companies, unions, political parties, so result may differ from first order intended effect.

Course offers 4 types of tools:

1)**Theoretical models/algorithms** Section 1 on social interaction models, evolutionary games and interaction models lay out ways in which micro interactions among agents can produce surprising results and evolve in market settings. Section 2 on algorithms to search for optimal on rugged profit or utility landscapes that have many optimum so local optimizing behavior fails to find global optimum; and ways machines do huge number of learning trials to dominate humans in brainwork.

2)Macro modeling/empirics: Section 3 power law links frequency of events to magnitude; and network interactions/graph links that provide way to build macro-conclusions from individual interactions but take interactions/ behavior/model as given or unknown black box.

3)**Big Data statistics** in section 4 to assess non-linearities, illuminate behavior of units with specified characteristics and obtain parameters for simulation counter-factual models, or to predict without understanding why

4)Small Data sets in section 5 focuses on ways to analyze the small number of big events – tail of the power distribution – in depth. Linked to medical analyses of individual patients.

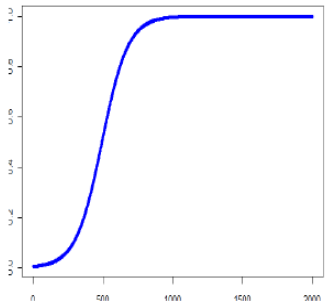
5)Simulation models. If you cannot experiment with world, simulate: section 5 gives systems dynamics differential/ difference equations and artificial agents and ways to obtain key parameters in simulations – via experiments or surveys.

Key to assessment of policy is counter-factual – what would happen if we did/did not change X, so simulate counter-factual. But ideology can dominate counter-factual. "You think Troika austerity failed in Greece? Ah, but the Invisible Hand would have destroyed society far worse without the policy/". Need ways to obtain key parameters .

Why discontinuous change is not math discontinuous

Because derivatives useful. Signature is large derivative around some point. Often measured by *continuous nonlinear curve* to allow us to differentiate and get handle on rates of change

Most popular continuous curve to measure discontinuous change is **logistic curve**. A one-parameter logistic is **P = 1/[1+ exp (-Bx)],** which is valued between 0 and 1. It rises slowly then rapidly then slowly as it approaches its max. It is steeper when B is larger. When logistic is very steep, it is comparable to a threshold with a jump. Virtue of the logistic is that you can differentiate while mimicking discontinuous jumps. "Sigmoids" of this form often arise from single peaked distributions. Given most single-peaked distributions you get a fast rise when you reach the peaked area, but only modest changes thereafter.



The derivative of the logistic is dP = B(1-P) P -- a parabola. At small or large P dP is small. Differentiate dP and you find that max dP is at P = 1/2. With a simple transformation the logistic becomes **LINEAR LOG ODDS RATIO**: ln(P/1-P) = -Bx. If the maximum value is A, you have a two parameter logistic, P = A/[1+ exp (-Bx)], The logistic can depend on many xs: $P = 1/[1+ \exp (- \Sigma B_i x_i)]$.

Lots of phenomenon follow this dynamics: modest initial change, sudden burst of rapid change, followed by slow movement toward the final value. Kauffman writes (p 57) "the rapid increase is the signature of something like a phase transition" – shift from one form to another. Logistic used in neural nets and in "deep learning" algorithms**.**

Economic adjustment toward desired value implies logistic growth curves.

Assume equilibrium, E* and that the firm/person adjusts by moving partway toward the equilibrium in period of time: dE/E = B (E*- E) so that you close B percent of the gap. This is a logistic, Write it as dE = B(E*-E) E and scale by E* so that x = E/E*, then dE/E= B (E*-E)–> dx/x= (BE*) (1-x) where the parameter in the logistic is BE*.

What generates discontinuities?

1)Positive feedbacks can produce big jumps in behavior. I bump you. You bump me a bit harder. I bump back a bit harder … You punch me, I punch you.

By contrast, negative feedbacks -- changes in a variable reduce its magnitude usually lead to stable equilibrium. Thus, one of the problems in generating discontinuous change from an equilibrium state is understanding what may lead negative feedbacks to turn into positive ones.

2)Interactions among variables can also produce jumps. A positive interaction from X to Y and from Y to X can lead to an explosive growth while negative interactions can produce explosive decline.When one variable has a negative impact on the other but the other variable has a positive impact on that variable, you can get oscillations.

A classic system is the predator/prey model:

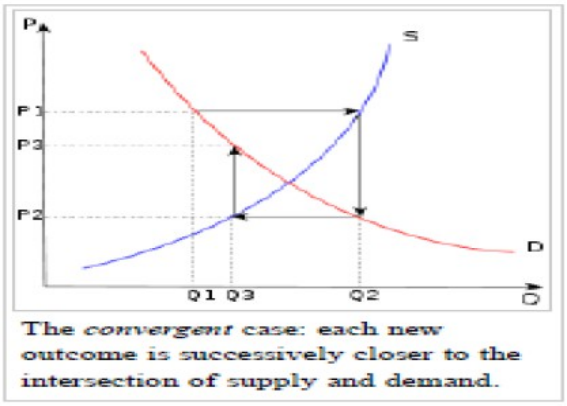
(1) dP/P = - d + aH ,where P = Predator population which grows with prey H and has death rate d
(2) dH/H = b - cP, where prey H = Host population which declines with P and birth rate b

Positive aH interaction in (1) More hosts--> more parasites.
Negative cP interaction in (2): More parasites --> fewer hosts.

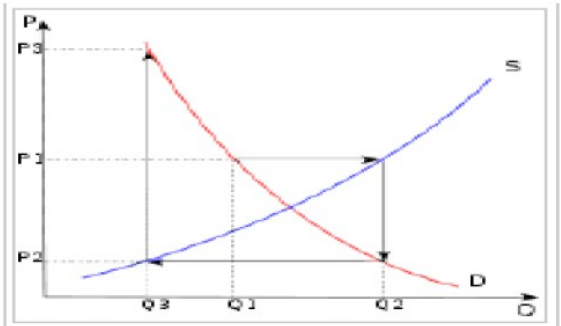
The negative feedback favors stability. If you start at equilibrium and add Hs, this increases P since it is more food for the predator in equation 1, which then reduces H (equation 2). Similarly if you add to P, H falls,which reduces But the model **can** also generate fluctuations with wild swings of P and H. O**utcomes depend on parameter values.**

Cobweb model is classic economics example, arising from **LAG** between the price signal and supply response. Classic cobwebs are: agriculture, where the farmer decides to plant in year 0 and harvests a year later; labor market where students decide which field to study and graduate N years later. PhDs or MDs have long training lags. CG = S + a W (-1) and W = X - e CG, where W=wage and CG = college graduates S = exogenous supply and X = exogenous demand. Solve and we get a difference equation: CG = S + aX(-1) -ae CG(-1)

This implies that big supplies in one period generate small supplies in the next – cobweb fluctuations. This model postulates that CG depends on lagged wages, which agents assume will hold in future. Other expectations process –> other dynamics. Note that if everyone is same, total disaster … so need heterogeneity.



The *convergent* case: each new outcome is successively closer to the intersection of supply and demand.



The *divergent* case: each new outcome is successively further from the intersection of supply and demand.

3)**Non-linearities in relations** . Shifts in linear relations produce continuous changes. When linear (log-linear) supply and demand curves change, it induces modest changes along the other schedule. With the "right" kind of nonlinearities you generate jumps; with critical parameter values and thresholds so that small differences can matter.

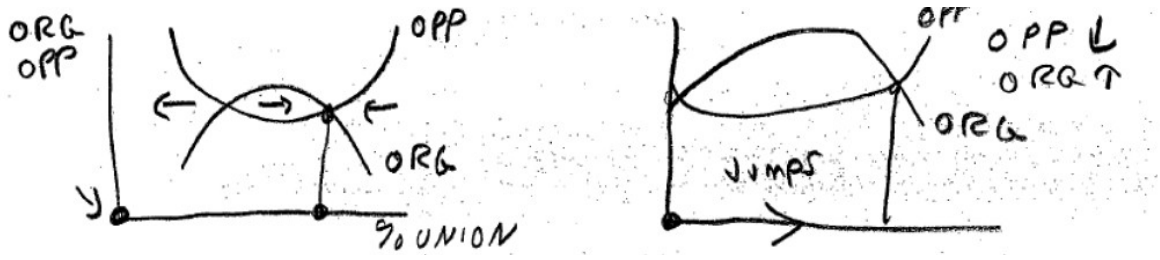
Consider worker protests for unions and firm opposition to unions. The graph below uses two non-linear curves to represent how firms and unions behave at different %union rates: ORG which measures union resources for organizing and OPP, which represents firm resources to oppose union organizing.

ORG curve shows that when % organized is low, unions have little organizing resources. If there are 10 members and 90 nonunion folk, the union will have to dun each member $10 to conduct an organizing campaign that costs $100. At higher density the cost of a campaign per member falls. If you have 20 members you raise the $100 with a $5 charge. When % organized is high, unions have little incentive to organize. This yields **NONLINEAR link between organizing effort and union density**, which we can write as a 2nd degree polynomial: $ORG = C + aU - bU^2$,

Similarly, generate **non-linear link between firm opposition to unions and density.** When density is high, firms pay the going union wage/practices to convince workers to remain nonunion; they suffer no disadvantage from the "level playing field" unions establish. At low density, firms lose profits paying union wage compared to nonunion competitors. The link between opposition and density is nonlinear, say, a 2nd degree polynomial: $OPP = D - cU + dU^2$

Changes in density depend on the difference between the two: ORG-OPP. Unions grow when ORG-OPP is positive and decline otherwise. The nonlinear reaction curves between density and behavior produce two equilibrium: high union (EU) and low union (US). When you perturb nonlinear reaction curves, you get jumps because it is in the interest of all people to\ shift from one state/behavior to another when others do.

Notice the divergence in densities toward two equilibrium in the union figure: you can think of US as essentially 0 union point and the EU as high union point, where EU boosts unionism because many EU countries extend CB contracts from union/employer federation to all firms/workers.



The Holy Grail of Policy: a trigger or catalyst so that a small change moves the world from bad state A to better state B at little cost. "Nudges" For many problems, it may not exist, but for some, there may be such a solution through increasing returns, non-convexities, non-linearities, interactions, etc.

Formal models clarify issues in public debate in ways that verbal discussion does not.

Suggested paper topics on discontinuities:

How do physical science fields deal with these phase transitions? Jump from wet rain to snow to ice.

Marxist/revolution analysis as efforts to derive discontinuous changes.

Addition of super-star player to a team can be discontinuous change in team performance.

Does market volatility increase the risk of financial crises? See https://www.weforum.org/agenda/2015/10/does-market-volatility-increase-the-risk-of-financial-crises/

Check hypothesis that increased instability or turbulence is leading indicator of coming discontinuity. In earthquakes? "Many large earthquakes are preceded by smaller rumbles known as foreshocks. However, there is apparently no way to distinguish these tremors from other small quakes that don't portend a larger tremor. At the same time, many large earthquakes do not seem to have foreshocks."