Human Social Dynamics:
Realistic modeling of complex interactive systems

http://InterSci.ss.uci.edu/wiki carries these lectures at http://intersci.ss.uci.edu/wiki/index.php/Complexity_summer_school with interactive links and background readings

Part 3 Realistic dynamical modeling

( these slides incomplete )
What was learned in part 1 of the lectures, reviewing modeling of social systems from archaeological through historical to the current period

...is that we cannot look at contemporary (or past) data in terms of correlations but need to look at human dynamics in terms of time-lagged causality that makes immediate everyday comprehension difficult.

Here in part 3 we look at dynamics
Keynes (1920:11-12)

“The great events in history are often due to secular changes in the growth of population and other fundamental economic causes, which, escaping by their graduate character the notice of contemporary observers, are attributed to the follies of statesmen or the fanaticism of [nonbelievers]…. [T]he disruptive powers of excessive national fecundity may have played a greater part in bursting the bonds of convention than either the power of ideas or the errors of autocracy”

With the tightening of the world economy, the poorer sectors become poorer, destabilized, and ever more vulnerable to raw material exploitation.

More failed states.
Failure to go through a demographic transition.
More children in the failed states to compensate for insecurity.
More child warriors exploited in the rush for raw materials in failed states.

Greater world population growth and pressure on resources, pressure for migration.

**More internal war.**
**More external war.**

These hypotheses will require testing not with correlational methods but by time-lagged multi-equation fitting for dynamical modeling (Lectures, Part 1).

Part 3 now resumes the topic of multi-equation dynamical modeling, starting with the dynamic coupling of sociopolitical conflict (e.g., internal war) and population fluctuations.
e.g. recall from lecture 1

China (200 BCE - 300 CE): population and instability

- Population
- Internal War

Log Population vs. War lag Rate of change

Phase diagram
This is Turchin's phase diagram for England, 1480-1800, for population size and sociopolitical violence as a pair of variables that drive one another interactively. Temporal movement here is **clockwise**. The dynamic is that the population reaches carrying capacity setting sociopolitical violence into play, which only recedes as population crisis leads to a collapse, initiating a new cycle.
Turchin tests statistically the **interactive prediction** versus the inertial prediction for England and China

Table 1. Comparing out-of-sample predictive abilities of the inertial and interactive models

Turchin (2005), in *Structure and Dynamics* eJournal

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Dependent variable</th>
<th>Correlation between predicted and observed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>1st half =&gt; 2nd half</td>
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<tr>
<td></td>
<td></td>
<td>inertial</td>
</tr>
<tr>
<td>England</td>
<td>population</td>
<td>–0.57</td>
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<tr>
<td>England</td>
<td>instability</td>
<td>–0.13</td>
</tr>
<tr>
<td>Han China</td>
<td>population</td>
<td>0.45</td>
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<tr>
<td>Han China</td>
<td>instability</td>
<td>0.39</td>
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<tr>
<td>Tang China</td>
<td>population</td>
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<td>Tang China</td>
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To resume the topic of multi-equation dynamical modeling, starting with the dynamic coupling of sociopolitical conflict (e.g., internal war) and population fluctuations, longitudinal hypotheses require testing not with correlational methods but by time-lagged multi-equation fitting for dynamical modeling (Lectures, Part 1).

Greater world population growth and pressure on resources, pressure for migration.

More internal war.
More external war.

BUT what the Turchin theory does not explain is why does the population curve, when sociopolitical conflict abates, not simply grow following a logistic or S-shaped curve, that is, more rapid growth when more resources are available, then slowing as more resources are used per capita.

Why does world population growth follow power-law or hyper-exponential growth?

We begin there and then go back to questions of time-law causality with respect to: What is it in human dynamics that generates power-law growth?

And the answer to that question is simply this: cities, based on exchange networks, are what generate power-law growth.

The hypothesis (nature article) is that in a network model of exchange it is the presence of the strategic use of hubs, modeled by the γ (gamma) parameter in the feedback cycles model, that is different from other kinds of networks.
1. hyper-exponential growth in population: Actual world level runaway population growth spurts, producing crises of resource scarcity, and subsequent flattening of growth rates.

*World population power-law or hyper-exponential growth spurts and flattening as shown in a semilog plot with successive power-law fits, 10,000 BCE to 1962 (which begins another flattening: we are in the crisis phase)*
What is it in human dynamics that generates power-law or hyper-exponential growth?

And the answer to that question is simply this: cities, based on exchange networks, are what generate power-law growth.

My hypothesis is that in a network model of exchange it is the presence of the strategic use of hubs, modeled by the $\gamma$ (gamma) parameter in the feedback cycles model, that is different from other kinds of networks.


http://eclectic.ss.uci.edu/~drwhite/Complexity/SpecialIssue.htm

http://eclectic.ss.uci.edu/~drwhite/pub/PMContFwd01.pdf
In part 2 we looked at three complex-network models with different processes in their main dynamic:

• Scale-free, leading nodes ($\alpha$)
• Small-world, diffusion ($\beta$)
• Social-circles with feedback, with both features ($\alpha$, $\beta$) plus the strategic use of hubs ($\gamma$)

But what is the connection between strategic use of hubs, cities, and population growth? Simply this: to support a city a network of exchange is needed and this network requires agents who search out and mediate optimal exchanges. This evokes the strategic use of hubs ($\gamma$) where the city is part of a signaling system involving these agents, as in the generative feedback model, in which production has also to be managed by agents who can deliver exports to be exchanged (or weapons to use for extraction) that will deliver imports that the city utilizes either for sustenance and supply of its activities (including production) and for reproduction. We have seen in part 1 how this operates in the world economy, and Algaze (2005) shows how it operates in the first cities.
We can then begin to model the causes of power-law growth in cities with results from the study of urban growth: 2007 Growth, innovation, scaling, and the pace of life in cities. Luís M. A. Bettencourt, José Lobo, Dirk Helbing, Christian Kühnert, and Geoffrey B. West PNAS 104(17):7301-7306.

The growth of cities is constrained by availability of resources and rates of their consumption. The general growth equation [1] assumes a quantity $R$ of resources used per individual, on average, per unit time, while a resource quantity $E$ is required to add one person to the population. An allocation of resources is expressed as that is, sustenance and replacement, where $\frac{dN}{dt}$ is the growth rate. Then

$$\frac{dN(t)}{dt} = \left(\frac{Y_0}{E}\right)N^\beta(t) - \left(\frac{R}{E}\right)N(t).$$

The solution of this equation is given by

$$N(t) = \left[\frac{Y_0}{R} + \left(N^{1-\beta}(0) - \frac{Y_0}{R}\right)\exp\left[-\frac{R}{E}(1-\beta)t\right]\right]^{\frac{1}{1-\beta}}. \tag{2}$$

City populations, as shown by parameter fitting for urban network input/output & import/export, exhibit $\beta>1$ in the sustenance component that includes support for the city’s production. This implies hyper-exponential growth.

All other species exhibit $\beta<1$ in their sustenance component. !!!!
For scale-free networks a generating parameter $\alpha=1$ for preferential attachment $p(k)=k^{-\alpha}$ will often generate log-log slopes 2.0-2.3 in a $(k=)$ degree distribution tail that enables hub search. The slope will be lower if the network has too few nodes and higher if too many nodes.

In a city network it's not the spokes (roads) around each city that constitute attraction as if only by “degree.” Rather it is something like the attraction coefficient for production and marketing agents in the Bettencourt model.

We can check if the gravity model for intercity migration satisfies the function we are looking for: here, attraction $\sim$ size$^\lambda$/distance$^2$.

Similarly, what values of $\gamma$, $\alpha$, and $\beta$ in the feedback model give the network searchability?

What we want to find for known city sizes in a geographic space is what value of $\lambda$ makes the network “hub searchable” in the same sense that Adamic et al. demonstrated for scale-free networks. I suppose it would be nice if the range of $\lambda$ that yields “searchability” contains the value of $\beta$ from the Bettencourt et al. fitting experiment.

http://eclectic.ss.uci.edu/~drwhite/Complexity/SpecialIssue.htm

http://eclectic.ss.uci.edu/~drwhite/pub/PMContFwd01.pdf
Figure 4: Cross-correlations of \( q \) for temporal effects of one region on another

Time-lagged cross-correlation effects of MidAsia \( q \) on Europe and the Silk Road trade on European \( \beta \) (ten top cities)
becomes fully globalized.
Fitted parameters for city size distributions in Eurasian Regions (\(\beta\) in Pareto I tail, \(q\) in Pareto II body, and their normalized minimum)
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Slides not complete, please stop here.
Rome: Sorokin's index of internal war

Turchin 2007 SFI talk
Western Roman Empire (Lewit 1991)

Turchin 2007 SFI talk
Popular Immiseration, England: 1250 - 1800

Turchin 2007 SFI talk

Year

Variables, log-scale, arbitrary const.

1200 1300 1400 1500 1600 1700 1800

Inv. wage

Rel. Pop
Bohemia, Moravia, and Silesia

- Hussite Wars (1420-36)
- Thirty-Year War (1618-48)
- Turchin 2007 SFI talk
CAGR: 1540-1870 (Wrigley et al. 1997)
Population push to cities
(a) Paris

Population of Paris (thousands)

(b) Urbanization

Percent of population in the capital

Turchin 2007 SFI talk
Novgorod

Turchin 2007 SFI talk

Amber beads per cultural layer

1000 1100 1200 1300 1400 1500
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In a city network its not the spokes (roads) around each city that constitute attraction as if only by “degree.” Rather it is something like $p(k) = k^{-\alpha \beta}$ where $\beta$ is the attraction coefficient for production and marketing agents in the Bettencourt model and $\alpha$ is the coefficient of the transport degree network. (E.g., what values of $\gamma$, $\alpha$, and $\beta$ in the feedback model let the network be searchable?)

We can check if the gravity model for intercity migration satisfies the function we are looking for: here, attraction $\sim$ size$^\lambda$/distance$^2$.

What we want to find for known city sizes in a geographic space is what value of $\lambda$ makes the network “hub searchable” in the same sense that Adamic et al. demonstrated for scale-free networks. I suppose it would be nice if the range of $\lambda$ that yields “searchability” contains the value of $\beta$ from the Bettencourt et al. fitting experiment.

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Boston: Lexington Press. 2006 in paper  
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