Civilizations as Dynamic Networks

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Society for Anthropological Sciences

Background paper Civilization as Dynamic Networks: Medieval to Modern, a project with Peter Spufford, assisted by Joseph Wehbe
Outline

• Background of medieval Europe
• Dynamics from initial conditions of European feudalism to evolving cities and urban trade network
• Network properties affecting network processes in evolution of cities
• Processes affecting evolving urban industries
• Factors in system decline and resurgence
The lead-up to the 13th C world-system and its economy was a period of population pressure and crisis as environmental carrying capacities were reached.

In the 14th C, economic depression set in, inflation abates and population drops, with famines beginning well before the Black Death. With the closure of the Mongol Corridor (Golden Horde) in the 1360s, the European trade network crashed.

What Came Before?
What was the world-system like at the end of the pre-classical period in 500BC?
These trade routes mostly form a tree, with a narrow cohesive core from India to Gibraltar.

Trade networks before 500BC were smaller, even more tree-like, and lacking cohesion.
During the classical period, trade routes become cohesive from China to France.
Cohesive extension of trade routes leads to a host of other developments...

(figures courtesy of Andrew Sherratt, ArchAtlas)
... including power-law growth of world population.

Before we go there, it helps to know that all power-law growth entails strong predictions from its singularity date (in this case 2030 ± 10) as the outer limit of sustained growth:

1. It necessitates a transition before singularity
2. It predicts cycles of diminishing length as singularity approaches

And if we take the departure from the trend to define cycles of change we can begin to study other changes ...
...we see cycles of population growth

Detrended World Population to 1800, in millions

Detrended as a percentage of prior population

Source:
White et al.
Cycles grow shorter as predicted by power-law growth.

England’s population cycles lag the World cycles, which are heavily weighted by China and India.

Source: White et al.
In Europe, population cycles are part of a **dynamic** that drives **monetization** in the 12th-14th centuries. Here is Peter Turchin's Nonlinear Time Series Analyzer for the detrended English population cycle, 1100-1800, with cycles growing shorter in 300-200 year periods. The cycles and their **correlates**, such as **competition**, **wages** and **inflation** are not purely endogenous, however.

**English Population**

peaks at 1310, 1650 (15,49);

troughs at 1450, 1770 (29,62), 0=1160

**Cycles grow shorter** as predicted by power-law growth.

Source: Turchin
Correlates that do not interact dynamically include:

- English Inflation cycles (David Hackett Fischer)

imitate

- Detrended English Population cycles (Turchin)
The inflation of land was far worse in rural areas: The less commercial, the more inflation (Spufford)

The periodization of the pop-war interactive cycles and the inflationary price cycles also supports Arrighi's thesis of an alternation of commodity and financial capital intensity
English sociopolitical violence cycles don’t directly correlate but lag population cycles. Detrended English population cycles, 1100-1900, occur every 300-200 years.

Source: Turchin
The population and sociopolitical crisis dynamic that drove Inflation also drove monetization and trade in luxury goods in the 12th-15th centuries. Inflation of land value created migration of impoverished peasants ejected from the land, demands of money rents for parts of rural estates, and substitution of salaries for payments in land to retainers,

**Effects of Inflation of Land on Monetization**

Monetization

(Variables affecting transition)

Thresholds

(to handle higher velocities)

Reorganization

(e.g., Division of labor, new techniques, road building, bridge building, new transport)

Merchants/agents Governments/agents Churches/agents Elites/agents

(Variables affecting transition)

Monetization

(Velocity of Money in Exchange)

Inflation

(Relative to Carrying Capacity)

In kind payment of serfs, retainers \(\rightarrow\) salaried laborers

Demand for

money rents

Peasants

to cities

Elites to cities

Conspicuous

consumption

Demand for

silver mining

Coinage

Demand for

prestige goods

Poverty forces more meltdown of silver

Real wages

(low)

Prices

Inflation

Demand for

money rents

Peasants

to cities

Monetization

(Velocity of Money in Exchange)
A cycle, however, does not make an interactive *dynamic*, which is a pair of variables that drive one another interactively, with lagged effects, rather than each operating under its own inertia. This slide shows an idealized phase diagram for a pair of interactive variables, which might be population sizes of foxes and hares, or population size of agrarian regimes with limited carrying capacity interacting with magnitude of sociopolitical violence that occurs as populations reach this carrying capacity and then recede – and the population crisis leads to a collapse, followed by a new cycle.

Where you are on this phase diagram predicts where you are going; this is not true for correlated variables.

Source: Turchin

This is also where environment comes into the dynamics.
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** (axes are reversed from the previous diagram). The dynamic is that the population reaches carrying capacity setting sociopolitical violence into play, which only recedes as population crisis leads to a collapse, leading into a new cycle.

Where you are on this phase diagram predicts where you are going; this is not true for correlated variables.
Turchin tests statistically the interactive prediction versus the inertial prediction for England.

Table 1. Comparing out-of-sample predictive abilities of the inertial and interactive models (from Turchin-Korotayev Supplement)

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Dependent variable</th>
<th>Correlation between predicted and observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st half =&gt; 2nd half</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inertial</td>
</tr>
<tr>
<td>England</td>
<td>population</td>
<td>−0.57</td>
</tr>
<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>
</tr>
<tr>
<td>Tang China</td>
<td>population</td>
<td>0.56</td>
</tr>
<tr>
<td>Tang China</td>
<td>instability</td>
<td>0.57</td>
</tr>
</tbody>
</table>
the freedom for newly monetized nobility to move to cities, the rise of elite competition and conspicuous consumption in the cities; and, in the French dominions, resettlement of nobility the largest city of times, and the most influential political capital, Paris (year 1400, after the pre-renaissance inflation and just before the collapse of Paris due to competing factions)

Source: Spufford
Inflationary cycles 1200-1993

England
(steeper in rural areas; flatter in major trading cities)

Source: David Hackett Fischer
Environmental limits interact with population and sociopolitical violence

In periods of crisis, further monetization (which proceeds today) drives Volume of trade (velocity of money).

This will transform those organizations and institutions situated at predictable network junctures

Each cycle leaves institutions, transportation, technology transformed and the next cycle builds upon these so there are millennial trends and increasing environmental capacity that also predict network-situated innovation

This happens in China and in India as well as Europe
Chinese phase diagram
Position in networks deflects how the cyclical dynamics affect individual cities

for example, (net 1) in the cohesive core of a trade network all cities may benefit; outliers less so as they suffer from middleman monopolies
Cohesive trade relations (gold nodes) supported the creation of wealth among merchants and merchant cities, with states supported by indirect taxation and loans.

[ Northern Europe is not well represented in Spufford's study (and these locations are not geographic), but the main Hanseatic League port of Lubeck had about 1/6th the trade of Genoa, 1/5th that of Venice. ]
Cohesive nodes (gold and red) in an expanded exchange network and further road identification (red=3-cohesive) shows a second cohesive accumulation center further to the east -- again, such cohesion supported the creation of wealth among merchants and merchant cities, with states supported by indirect taxation and loans.

Now Northern Europe is represented (and the locations are geographic):
the main Hanseatic League port of Lubeck had about 1/6th the trade of Genoa, 1/5th that of Venice.
Monetization and growth in the volume of trade.

In Europe of the 13th century, described in Spufford's (2002) *Power and Profit: The Merchant in Medieval Europe*, capital cities first sprang into prominence with a remarkable growth in urbanization, monetization and government. With France as the leading landed kingdom, Paris was the leader in population, attraction and influence.

Lets look at an example of trade: raw material (wool), shipping (from ports), and manufacture (woolens as clothing)

Nodes for cities are sized here according to population; middle and larger sizes are also capital cities.

(Net 2)

The netflow thesis: organizational transformations occurring in this period, which set the foundations for modern Europe, were driven by the cyclical dynamic of interaction between demography and sociopolitical violence affecting monetization, velocity of trade.
Raw wool production sites

GIS mappings of sources of raw wool (sheep) in Spufford's European trade network will begin to illustrate geographical distribution of trade potentials.

Nodes for cities are sized here according to population; middle and larger sizes are also capital cities.

Source: Peter Spufford 2002 data transported to GIS
Manufacture of woolens to make wool cloth, clothing

(Source: Spufford's 2002 European trade network data transported to GIS)

Nodes for cities are sized here according to population; middle and larger sizes are also capital cities.
Seaports with wool exports or manufacture of woolens

(Source: Spufford's 2002 European trade network data transported to GIS)

As an example of *(net 2) netflow transformation in agent space*, agents from lowland countries in north Europe organized wool trade contracts out of London, but in the 1200s Florentine and other agents with cheaper sources of credit took over the trade from London, displacing the Flemings.
Competition over the Wool / Woolens trade (12th C map)

Node sizes:
- None
- Raw wool
- Woolens
- both
- Port
- Raw+Port
- Woolens+Port
Because **sea routes** opened cohesive exchange cycles as alternatives to land routes, a **positional similarity analysis** reflects a **cohesive and non-monopolistic** trade network. The importance of land versus sea routes oscillated during the 12th-15th centuries.

The split in Genoese (western and Atlantic) and Venetian (eastern) routes is also reflected in the circular positional structure, showing how they compete for trade.

Genoa dominates the core cities at the lower right, but their cluster and that of more peripheral cities at the upper left each has its banking cities. Venice is more a single eastern.

Now for a detailed look at how population cycles and trade networks promote industries...
Productivities are overlapping, crosscutting and interlaced in complex ways
Note how an industrial "blue banana" construction is taking place with communications in the left column, art works in the middle and linens on the left, i.e., circulation among the NW-SE poles; while capitals show a political vacuum of smaller polities in between, and trade fairs fill in this vacuum by providing decentralized marketing institutions.
Productivities are overlapping, crosscutting and interlaced in complex ways.
Monetization entails a counterflow of commodities and credit that facilitates trade. Credit networks (e.g., banking) are also a means of distributed control.
the banking network, main routes only (again, geographically).

(Net 5) Control networks often rely on unambiguous centralized spines but their operation relies on feedback in cohesive networks.

the spine of the exchange system is tree-like and thus **centralized**. It is **land based**. Linking the four parts was Alessandria, a small stronghold fortification built in 1164-1167 by the Lombard League and named for Pope Alexander III. At first a free commune, the city passed in 1348 to the duchy of Milan.

Note again the closeness of Genoa to the center, and the exclusion of Venice.
main routes in the banking network, **plus maritime** (Genoa and Venice).

Now we see how Venice is encapsulated in its own eastern subnetwork, competing with Milan and Genoa.
Betweenness Centralities in the banking network

Betweenness centrality in the trade network ought to predict accumulation of mercantile wealth. Genoa has greatest wealth, as predicted. On September 7th 1298 Genoa defeated the Venetian fleet in battle.
(Net 7) Flow centrality (how much total network flow is reduced with removal of a node) predicts something entirely different: **the potential for profit-making on trade flows**. It necessarily reflects flow velocities central to the organizational transformations undergone in different cities, as Spufford argues. This type of centrality is conceptually very different and distributes very differently than betweenness and strategic centers like Venice or Genoa, which are relatively low in flow centrality.
Flow centrality (how much total network flow is reduced with removal of a node) reflects the potential for profit making on trade flows, and reflects the **flow velocities** that Spufford argues are central to the transformations that different cities undergo.

Indeed, at the high end are **Bruges**, undergoing commercial transformation, **Troyes** of the Champaign Fairs, **Malaga**, engaged in transformation at the Muslim/Christian frontier, and **Tunis**, involved in Muslim political transformation,

Troyes is engaged in a transformation of agent space involving money and trade representatives that leads to the migration of the Provins nobility, the wealthiest in France, to the new political capital at Paris at century’s end.
Some rough observations

Next: The first modeling problem is to take the constraint set for each time period - raw material sources for production, distribution of producers, location and magnitude of consumer population, cost and risk of available trade route usage, and political configurations, including warfare, and derive the commodity trade flows and magnitudes among nodes as (1) a linear program problem given marketing sites or (2) an agent-based simulation in which mercantile agency and marketing sites transform and co-evolve with changes in trade flows.
Learning to overlay networks on geophysical terrains (press for zoomable GIS images)

A preview of things to come: the network shown will be capable of changing dynamically from the activated website to show evolution through time.

The svg projection also has the capability of showing agents moving over the network and geographic space.
The network variables are not static but changing in terms of flow velocity and magnitude.

Table 2: Commodity Production City Frequency by Generational Time Periods

<table>
<thead>
<tr>
<th>Era 1</th>
<th>Era 2 (13th C)</th>
<th>Era 3 (14th C)</th>
<th>Era 4 (15th C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 1 1</td>
<td>1 1 1 1 1 1 1 1</td>
<td>1 1 1 1 1 1 1 1</td>
<td>1 1 1 1 1 1 1 1</td>
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<td>3 3 3 4 4 4 5 5</td>
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<tr>
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<td>5 0 5 0 5 0</td>
<td>5 0 5 0 5 0</td>
<td>5 0 5 0 5 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industrial Commodity</th>
<th>Code Num.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woollens 1</td>
<td>1</td>
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<tr>
<td>Fustians 2</td>
<td>2</td>
</tr>
<tr>
<td>Linens 3</td>
<td>3</td>
</tr>
<tr>
<td>Cottons 4</td>
<td>4</td>
</tr>
<tr>
<td>Silks 5</td>
<td>5</td>
</tr>
<tr>
<td>Carpets 6</td>
<td>6</td>
</tr>
<tr>
<td>Tapestries 7</td>
<td>7</td>
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<tr>
<td>Paper 8</td>
<td>8</td>
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<tr>
<td>Printing 9</td>
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<tr>
<td>Manuscripts 10</td>
<td>10</td>
</tr>
<tr>
<td>Artworks 11</td>
<td>11</td>
</tr>
<tr>
<td>Brass 12</td>
<td>12</td>
</tr>
<tr>
<td>Brass canon 13</td>
<td>13</td>
</tr>
<tr>
<td>Armor arms 14</td>
<td>14</td>
</tr>
<tr>
<td>Glass 15</td>
<td>15</td>
</tr>
<tr>
<td>Pottery 16</td>
<td>16</td>
</tr>
<tr>
<td>Sugar refined 17</td>
<td>17</td>
</tr>
<tr>
<td>Soapmaking 18</td>
<td>18</td>
</tr>
<tr>
<td>Coalmining 19</td>
<td>19</td>
</tr>
</tbody>
</table>

* Data incomplete
Among the structural changes in the network are the developments in commodity production studied through time by means of: (1) entailment analysis (2) lattices.

In the figures below for each of the 14 time periods the cyan nodes along the bottom of the graphs represent varying populations scaled from:

>200,000 >100,000 >50,000 >20,000 >10,000

Other nodes are sized according to their frequency distribution among cities:

1=yellow, 2=green, 3=red and so forth (large blue dot for woolens has incomplete data)

Except for the mutual exclusion between linens and ports, a directed line indicates that populations producing one item (or of an entailed size) will also be producing the other item (or be of the size entailed).

Here, between 1175 and 1200, silk production is moving down the town-size hierarchy, while manuscript production is appearing in 1200 in the largest city (Paris) but is always found in those with >50,000 (Paris and Arras); pottery and papermaking co-occur in both time periods but not in association with any specific population sizes.
1225, adds: glass >100,000 and armor (→ linens) entail cottons
1275, adds: artworks → 20K, coal & armor entail brassworks

1250, silk moves back up and entails cottons (→ 20K)
1300, e.g., paper & armor shift to towns >10K and 20K
1325 e.g., fustians come into entailment 4-chain with cottons $> 10K$
1350 e.g., cottons replaced by fustians $> 10K$, → linens
1375 e.g., paper moves up the size hierarchy $> 50K$, → silk→
1400 e.g., linens enter entailment 5-chain with fustians $> 10K$
1425 **brass** now entailed by **canons**

1475 **manuscripts** replaced by printing press
Dual Intersection Lattices show the complete detail of how industrial hierarchies distribute with respect to city hierarchies.
Polities and External War

As industries rose in Europe late in the 1100s with the population boom, de-feudalization, urbanization and monetization, what was happening in the larger context of political units: states and empires?

Europe was an economic periphery with centers of royalty and one great Kingdom in France and many smaller capitals of growing consumer demand that fed the transformation of trade, but the goods most desired by nobility were those of India and China.

Arrayed around the southern Mediterranean from its western edge in Spain all around to Turkey were the great Islamic Caliphates, the sources of scientific knowledge and vast riches as well. Islamic polities held the ports through which all the most lucrative European had to pass.

Recall that the capital of the Roman empire had moved to Constantinople, which was run by the Greeks and was the greatest center of wealth and riches in the Pan-European realm, and center of E Orthodox Xianity. As the Spanish kings pushed against the Caliphates to the South, Seljuks and later Ottoman Turks pushed up against Constantinople.

Resulting from a series of mishaps, European Crusaders in Constantinople in 1204 turned against their hosts and completely sacked the city, leaving it greatly weakened and ultimately defenseless against the Ottomans.
Political and warfare dynamics (Turchin 2004) and constraints

12thC.jpg polities, with conflict frontiers, ethnogenesis across metaethnic political boundaries, and arrows showing movement in the next time frame.

Warfare on the frontiers of Europe were primarily along religious boundaries.

In the center were the fractured remnants of the Holy Roman Empire, a zone of competition but ‘relative’ peace and trading fairs.

Source: Peter Turchin 2004
Christian Crusades run into the Baltic

The European polities are so weak compared to the Mongol military they would have been no match whatever, but the Mongols turn back to China over an issue of succession.

Source: Peter Turchin 2004
14thC.jpg polities, with conflict frontiers, ethnogenesis across metaethnic political boundaries, and arrows showing movement in the next time frame.

As velocity of trade transforms European organizations, small polities harden, Castile expands, France expands, Leagues form in Germany, but the Ottomans push against Constantinople.

Source: Peter Turchin 2004
15thC.jpg polities, with conflict frontiers, ethnogenesis across metaethnic political boundaries, and arrows showing movement in the next time frame

Velocity of trade decreases, Paris becomes a remnant, but Europe remains a trading zone...

Ottomans take Constantinople in 1442, and then the Aegean-Balkan south. The Renaissance is fueled by recovery of materials from Constantinople.

Source: Peter Turchin 2004
Afterword

The dynamics of pop-war in civilizational networks over shortening 300-200 year cycles plays the role of the profits pump dynamic that we have identified in the contemporary world economy (Smith and White 1992).

The latter also has a shorter business cycle as well as a longer secular (centuries-long) cycle, and profits alternate with other forms of capital as the shorter-wave economic driver.

Another example in the biotec industry (Powell, White, Koput, Owen-Smith 2004) we identified a year-to-year pump-for-innovation dynamic in which the cycle is the rise and fall of corporations. He pump is an outreach from players at the cohesive center of the field to newcomers on the peripheries, boosting their cohesion, which then provides a window to scan and ladder to climb for successful innovation in the industry. Longer cycles in the field itself would be expected.
Overview

Environmental limits interact with population and sociopolitical violence

In periods of crisis, further monetization (which proceeds today) drives

Volume of trade (velocity of money)

which will transform those organizations and institutions

situated at predictable network junctures

The dynamics of the modern world system is evident in the long 13th century

Arrighi’s thesis of an alternation of commodity and financial capital intensity

fits into the periodization of the pop-war interactive cycles

and the inflationary price cycles

Each cycle leaves institutions, transportation, technology transformed

and the next cycle builds upon these

so there are millennial trends and increasing environmental capacity

that also predict network-situated innovation
The rising levels of flow centrality in the Lowland Countries of Northern Europe, even in the 12th C, presages a different type of capital accumulation -- profit making rather than commodity trade betweenness.

Giovanni Arrighi sees this swing as an alternation in forms of capital accumulation from Genoese commodity trade hegemony in the early 13th century (commodity) to the eventual rise of Dutch financial capital hegemony in the 17th C., with the financial center shifting to Amsterdam.

and after that back to the commodity form of capital accumulation with British hegemony
Europe in the 13th century can be considered a zone of peripheries and semiperipheries of a world system based in China and India, whose products were much more in demand in Europe than the reverse, hence the perpetual drain of bullion and coinage to the East.

The same routes that carried trade also spread disease, as in the case of plague that severely reduced European and especially urban populations in successive epidemic waves.
Abu-Lughod draws the congruence between trade routes and spread of the Black Death, circa 1350.
Their own historian wrote that the Crusaders never had imagined that there could be a city like this anywhere in the world. These men, who came from mud huts with thatched roofs, gaped in astonishment. Here it was: the imperial city, called "Tsargrad" by the Russians, greatest in the world, hub of culture and commerce, center of the civilized world. Here was more wealth than in all of Europe put together. This was the inheritor of the Roman Empire. Here was a city of churches, monasteries, palaces, towers, forums, arenas, bazaars, baths, libraries and monuments. Here stood Hagia Sophia (Holy Wisdom), crowning glory of the city, marvel of the world, built by Justinian six centuries earlier. The Theotokos being the patron and protectress of the city, over a hundred churches were dedicated in her name. Her maphorion, which twice had saved the city: once from the Avars and once from the Russ', was kept in the Blacharnae Church, as was her wonder-working icon. The Theotokos' belt (zone) was preserved in the Chalkprateia Church in the copperware district. In the center of the city stood the Church of the Holy Apostles, built as a shrine for St. Luke, and which also was the custodian of the relics of Sts. Timothy and Andrew, as well as the head of St. John the Forerunner, in whose name there were some 35 churches. St. John Chrysostom was brought to this church from far-off Armenia for burial eight centuries earlier. Elsewhere were the relics of St. Stephen and St. James, as was the wood of the True Cross found by St. Helena. The Pantacrator Monastery was the guardian of the Icon of the Theotokos of Nicopeia, which preceded the emperor into battle. At Blacharnae stood two gigantic pillars, on the tops of which sainted stylites in past centuries had spent the remaining years of their lives in prayer and meditation. Throughout the city were numerous other churches and monasteries which guarded the many relics of Apostles, martyrs and Church fathers. Such was the city before which the western armies stood in awe and disbelief. 

-- http://aggreen.net/church_history/1204_sack.html
Dynamics of groups and institutions: Their emergence, co-evolution and environment

In conclusion:

Environmental limits interact with population and sociopolitical violence

   In periods of crisis, further monetization (which proceeds today) drives
   Volume of trade (velocity of money)
   which will transform those organizations and institutions
   situated at predictable network junctures

The dynamics of the modern world system is evident in the long 13th century

   Arrighi’s thesis of an alternation of commodity and financial capital intensity
   fits into the periodization of the pop-war interactive cycles
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Each cycle leaves institutions, transportation, technology transformed

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