Causality of Network Configurations in Historical Dynamics:

Some Hypotheses and Evidence[1]

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Abstract. This research investigates historical processes in Medieval Europe (using Spufford 2002, 2005 among other sources) in relation to (1) changing network configurations of trade and warfare, and (2) changes in the shape of city size hierarchies. This paper summarizes results in the form of general hypotheses consistent with findings from the Medieval period and begins to consider these hypotheses in the context of historical dynamics over the last two millennia. Each hypothesis is tested with available data at the largest scope and time depth available to this project.

The most important results are that prior to Eurasian globalization, which begins in the second millennia, the sizes of trading networks oscillate slowly between more global expansions and more regionalized contractions. The timing of these long run oscillations tends to anticipate by 30-100 years the onset and termination dates of detrended rise and fall in regional population as posited by Turchin and Nefedov (2006) in their findings about regional secular cycles. These involve population oscillations with rises coupled, with appropriate generational time lags, to social conflict due to rising scarcity. Hence it would appear that expanding/contracting economies (and network changes) drive population changes that in turn drive social conflicts. The dynamics is interactive in that social conflicts, with appropriate lags, also drive falling population levels. This pattern appears to continue in the second millennium, but with the addition of significant city growth within the trade network.

In the second millennium, city size topologies also oscillate in the long run, between size distributions with more global network hubs and those with more localized hubs. Further, (1) city size topologies rise and fall with trade network oscillations, and (2) also tend to lead by 30-100 years the starting/ending dates of Turchin and Nefedov's secular cycles. A series of hypotheses is given that would explain why and how long run historical oscillations are embedded in other long run but faster oscillations, with average length of cycles diminished by half in each

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[1] This paper, originally titled "Power and Profit in Europe and the Near East: Network Dynamics in the Early Renaissance 1175-1500," was originally presented at the annual meeting of the ISA in San Diego, March 2006. It forms part of several linked projects on civilizational networks. The Medieval project involves collaboration with Peter Spufford, University of Cambridge. The City Sizes project involves collaborations with Nataša Keyžar. Support from EU project ISCOM, "Information Society as a Complex System" is acknowledged for both projects. The larger project, Civilizations as Dynamic Networks, forms part of a Santa Fe Institute Working group for which SFI support is acknowledged.

embedding. This dynamic embedding runs from network sizes and city topologies cycling at about 440 years in average length, secular cycles averaging about 220 years, and leading polity cycles averaging about 110 years. Additional hypotheses show how the two phases in the longest cycles (more globalized networks versus more regional networks) tend to correlate with financial versus commercially oriented trading networks, and how two very different network measures of the centrality of cities within their trading networks make very different predictions about accumulation of commodity wealth as productive capital and accumulation of financial capital.

Structural cohesion in trade networks also tends to predict the capability of different identifiable trading zones to operate through supply-demand pricing as opposed to price-setting as a function of monopoly positions along uni-connected trade routes. This connects with the temporal processes of secular cycles in which rising populations produce scarcities that lower wages and in turn raise inflation. Inflation rates tend to diminish proportionally to the extent of their structural cohesion or multiconnectivity in the trading zone. At every level in these linked hypotheses and findings, network changes are found to affect historical dynamics and offer major improvements in specific predictions about which cities will tend to undergo different changes, and when.

Network analysis has a potential to displace - by predictions about concrete historical processes as they operate locally and globally in different network contexts, what have previously been regarded as unexplained path dependencies. Considering the composite of these interconnected hypotheses as it forms a general model of embedded historical dynamics, an emerging theory of historical processes of change begins to take shape in which network embeddings, differentiation of time-scales, and general predictions at different time scales and covering different localities in terms of network interactions involving of trade and warfare form a coherent dynamical system. Finally, because the longest-term observable pulses in this system are those toward or away from more global networks of trade, this theory contains an answer, not fully investigated as yet, as to why we observe the synchronization of secular cycles and changes in city size hierarchies as between west and east Eurasia, but not south Asia. The explanation is that once trading networks of one macro region interconnect with those of another, i.e., where one or both are sufficiently expanded to do so, then the two economics and their secular cycles have a potential to synchronize that was not present previously, and that need not involve other regions that remain disconnected.

International comparisons in the historical long run, at the global or comparative regional level, often rely on ideal type classifications, as in the study of varieties of capitalism (VoC) theory. This in turn may tend toward an implicit and troubling functionalism. Relational or interactional models, as in varieties of world historical system (VoS) approaches, tend to be both conceptual and narrative histories rather than based on explicit representation and analysis of network interactions. This paper draws some of its concerns and orientations from both approaches but the framework used here is more compatible with the conception of civilizations or VoS as interacting networks, in which the elements are cities, and a variety of other groupings operate at different levels of structural cohesion. Network conceptions are significantly adapted to realistic dynamical studies of civilizations as networks, i.e., defined by connectedness and interaction, the better to achieve a more precise representation and analysis of interactions.[2]

Let me begin with the idea of structural cohesion: a network concept that allows interacting units, larger than one or two elements, to be identified within a larger network. It is a scaleable concept, in that for any given network of elements (e.g., cities) and relations (e.g., trade route adjacencies), a subgraph of the network is cohesive k-component if and only if it is a maximal set of elements for which there are k or more independent routes between every pair of elements in the set, connecting a grouping of elements within a set either directly or through paths within the set. For example, a clique, with k+1 elements, which is a maximal set of elements all of which are directly connected, is k-cohesive. However, cohesive links may be more widely distributed within a network to form k-cohesive sets with many more elements than those in a clique.

In this conception of interacting units, I am using a theoretical concept – structural cohesion – that can be applied to a concrete empirical network, historically observed through time, in which changing configurations of elements can be uniquely and precisely described. Predictive cohesion theory (PcT) states that for any network of commensurate and "positively" connected

[2] Wilkinson (1991:160) defines "a trade-connected area as an 'oikumene' or 'ecumene,'" "'world systems' as militarily closed social-transactional networks with an autonomous political history," and 'civilizations' (p. 113) "using criteria of level-and politicomilitary-connectedness rather than the more customary criteria of level-and cultural-uniformity."

elements, other things being equal (including group size), subgroups of elements will have (1) greater potential to coordinate and cooperate in their activities (both within and vis-à-vis external relationships) to the extent that they are structurally cohesive (i.e., higher levels of k-cohesion), and (2) greater resistance to disconnection by removal one or more of their members. One of the most fundamental insights of graph theory, proven as a theorem, is that a maximal subgroup of a network as defined by the multiconnectivity of the routes that hold it together (its level of k-cohesion) is identical to a maximal subgroup that cannot be disconnected by removal of fewer than k of its members. One might take the level k of a maximal structurally cohesive group *g* as a measure of its power. The size, s_g, of such a group will necessarily exceed k members but is not otherwise limited. If c_g is the measure *k* of the group's cohesion, then $p_g = c_g s_g$ might be taken as the cohesive power of a group to coordinate larger sets of people capable of cooperating in their activities, and to remain resistant to external disruption. A key network variable for historical dynamics (Turchin 2003, 2005, 2006: *asabiya*), for example, is the capacity of a social group for concerted collective action. Turchin's use of *asabiya* in this regard is the "group solidarity" or psychological and motivational aspect of groups with structural cohesion, which is the supportive relational aspect of this collective action capacity. Predation or external war by growing empires against groups across a metaethnic frontier, according to Turchin's theory of collective dynamics, will tend to increase those groups' resistance through increases in their *asabiya*. Competition within groups already established, e.g., among elites or between leaders and commoners within an aging empire, will tend decrease their *asabiya*.

Structural cohesion[3] is a powerful concept for studying civilizational networks because it goes beyond inferences about "solidarity" from observed historical events, and helps to identify various types of emergent units such as trading blocks of cities, regional units, polities, or clans, for example, from the pattern of linkages between entities. The linkages that define these blocks may vary: the first three of these four examples might show up in inter-city trade networks, but political alliances might show up on all four; while kinship links might be visible in emergent units for the last two types of groupings. Structurally cohesive groups typically have many "surplus" links that are present but are beyond those required for their current level of k-

[3] White (1997), Brudner and White (1998), White and Harary (2001), Moody and White (2003) , White (2004), White, Owen-Smith, Moody and Powell (2004), Powell, White, Koput and Owen-Smith (2006).

connectivity. This makes structurally cohesive groups socially robust, and robust as well as network unit-finding measures. Their robustness and uniqueness properties make them ideal for historical, governmental or even observational data that are incompletely counted or sampled. Further, they allow us to define subgroups within a network that may overlap, because, for example, two distinct k-connected subgroups may have up to k-1 nodes in common. They may also be stacked hierarchically, since a k-connected subgroup will by definition be embedded in a (k-1) connected subgroup. Networks, however, may be embedded in a variety of ways.

Role affinity[4] constitutes another network concept that is less robust than structural cohesion, but that helps to identify differential patterns of ties between units that are defined, recursively, by their patterns of ties. Unlike the uniqueness of structurally cohesive subgroups within a network, many different approximations may be used to measure role affinities. This is because none of the underlying concepts—approximations to structural equivalence (the maximal set of elements connected in the same way to every other element) or to regular equivalence (maximal subsets connected in the same way to some element(s) in every other regularly equivalent subset, a highly recursive concept)—cannot be expected to be perfectly realized in nontrivial ways in actual networks. Further, even the set of good approximations to a given "role model" may not converge to a unique solution (see White and Reitz 1984). Finding role affinities resembles the problem of finding the best abstract pattern (rather like a root metaphor that fits several different situations) with constituent roles and relations between them, into which every element in the actual network can be mapped together with others in a way that preserves the pattern. This is rarely if ever perfectly achieved in terms of a reduced blockmodel of roles or abstract positions in a network.

Patterns in warfare or trade links can be identified and seen to change over time in civilizational networks at the level of interactions between cities or nations, using structural cohesion or role affinities, or both, and of course, along with many other well defined network properties that can be measured. While paying a price in lesser robustness and uniqueness, however, the various definitions used for role affinities can and do find broad varieties of patterns in networks

[4] Sailer (1978), White and Reitz (1984), Smith and White 1992).

(different and far broader but less precise than those for structural cohesion). These might include a hierarchical pattern that is defined by directed edges, say of subordination/ superordination, or patterns where the relations between pairs of blocks reflect differential magnitudes of directed flows of commodities. Smith and White (1992), for example, applied the role affinities measure of White and Reitz (1984) to patterns in international trade flows in the 1965, 1970, and 1980 world economies.

The Smith and White (1992) study of positions in the global economy sidestepped the problem that is created by trying to map nodes in a network into strictly equivalent and categorical blocks by using a looser concept of roles that allows overlap in positional memberships, as where a country has trading relations similar to those of the periphery and *but also* to those of the semiperiphery. Such a country could be considered intermediate to the two positions, or an occupant, in part, of both. The network study of positional affinities in the global economy did not attempt to identify mutually exclusive roles, but instead measured the extent to which pairs of nations approximated a common template of pairwise role affinities. By taking advantage of the fact that role affinity measures only approximate regular equivalence, it avoided having to split the nations up into discrete blocks. Then, when our pairwise role affinity measures were scaled by eigenvector/eigenvalue methods (SVD), circa 87% of the variance in the scaling of pairs of nations in the 63 x 63 role affinity matrix fell on the first eigenvector. This was a strong result that supported a continuum model of core-periphery relations in the world economy, a result that is predicted in some of the VoS theories. One could of course "see" subgroups of nations, such as those of the semi-periphery, as clusters in the scattergram of loadings on the first and second eigenvectors, but continuum scaling suggested no uniqueness criteria for the boundaries of clusters. The problem of trying to determine "categories" or topologies of players in world historical systems has, of course, plagued VoS theories. The advantage of our role affinity methods was that, by showing a stable 1-dimensional main component of the role hierarchy in the contemporary global economy, we could measure *mobility* in the global economic hierarchy with great precision.

Over longer periods of time, for more precise studies of similarity and change in network or structural patterns in civilizational networks, factors affecting variability in world historical system structure (VoS) and changes in the forms of capitalism (VoC) need to be studied in terms of *networks of cities*, and not just by trade flows, but also by shifts in *trade routes and their transport costs and capacities* as well as the *costs and transport blockages created by enduring or disruptive conflicts.* National entities are simply not stable over time and space, and thus do not provide a suitable or comparable unit of study for modeling civilizational dynamics. Further, it is the development of industries that emerge out of the innovations that occur in cities that largely make for the economic and population growth that create and support civilizational networks (i.e., networks primarily of trade, and secondarily of war). War is typically associated with organized political units, but political units and their changing boundaries can also be seen as emergent structurally cohesive units whose core consists of changing blocks of cities, sometimes mutually exclusive blocks, and sometimes overlapping. And, in general, forms of embedding, hierarchy and linkage are subject to change, each of which can be done once a network study has found a sufficiently adequate representation of multiple types of entities and multiple types of relations, i.e., so as to begin the study the dynamics of how processes endogenized in the network interactions over time (and of course, the *attributes* of the interacting entities) affect one another.

Analysis of networks of intercity trade, industries, and populations, emergent and changing polities comprised of cities and their hinterlands, and the warfare patterns of changing polities, which also realign their inter-polity cohesive configurations through war, alliance, kinship, and conquest, then, ought to constitute a sufficient and minimally required framework for studying international relations.

The concepts so far discussed form the basis and framework for the larger project, *Civilizations as Dynamic Networks*, within which I have been studying, along with colleagues,[5] Medieval Europe as a test case, expanding next to the Near East, and then to all of Eurasia and North

[5] Principally, Peter Spufford, but also: Nataša Kejžar, Constantino Tsallis, Ralph Jester, Laurent Tambayong, with assistance from Joseph Wehbe.

Africa. Project goals are to identify and represent realistically both the dynamics of interaction and changes in network structure as they occur or emerge in time and space.

Relevance of some basic network concepts, measures, and hypotheses

Throughout the paper I will use the "cycles" not to refer to oscillations of world historical system variables that have uniform amplitude and periodicity, but processes of oscillations are roughly similar amplitudes and periodicities that might be due to dynamical interactions among macro-historical variables such as population number, or volume of trade or trading network areas.

Hypothesis set 1. In intercity trade-route networks, both land and sea-routes, the degree and distribution of structural cohesion directly conditions (and may respond to via the construction of new links) the potential for supply and demand market pricing. Disconnected cities obviously cannot trade broadly, and 1-connected cities allow single nodes in the routes connecting them to act monopolistically as unique intermediaries.[6] It is only with 2-connected cities (2 or more node-independent paths) that there is a choice between *which* alternate routes connected by intermediaries provides the best product quality for price, gain, or exchange of goods. A single pair of 2-connected cities, however, by definition, already constitutes the making of a circular route, a 2-cohesive unit, or, if maximal,[7] a 2-component set of routes. Further, the maximal expansion of a 2-connected unit is a unique 2-component; and the same applies for all k-connected units maximally expanded to k-components. Assuming that trade can flow in both directions even if single commodities flow only one-way, the 2-components of a trading network are the minimal units that allow flexible supply-demand pricing. The k-components of a trading network provide more market choices the higher the k, and thus *the likelihood of supply-demand pricing will increase monotonically with the level of structural cohesion because of greater choice among alternative buyers or sellers*; while conversely, 1-cohesion, which entails

[6] A good example (McEvedy 1956:84) is "the Parthians complete control of the last stage of the [silk] route," ca. 230 CE, about which the Romans "protested that the Parthians grossly overcharged them."
[7] Mathematically, what maximal means is that nothing can be added, e.g., to a subgraph of a network, so as to enlarge a set of elements while still preserving a property of the set, e.g., the 2-cohesion of the subgraph.

monopolistic cutpoints in trade routes, restricts the kinds of choice of partners among alternatives that are necessitated by supply-demand pricing.

Sample test 1.1: Using the medieval data published by Spufford (1989, 2002), we find for Medieval Europe that in inflationary periods, the inflation rates in a given city are higher the lower the structural cohesion in their trade routes. This occurs mostly because inflation happens in times of greater resource scarcity,[8] so that areas subject to 1-cohesive sets of trade routes will be at greater risk due to the greater pressure on their trade intermediaries to take advantage of holding monopolistic positions that have the power to raise prices somewhat arbitrarily given the lack of alternative suppliers. The inflationary periods in different regions or polities tend to correspond to the population growth phases of secular cycles identified by Turchin (2003, 2005, 2006) that lead also to internal conflicts within polities and to the decline phases of secular cycles, which correspond to those identified by Goldstone (1991, 2003) in his Structural Demographic Theory.

Sample test 1.2: Over time, the Medieval trade data collected by Spufford (2002) is consistent with the view that as imperial conquests or wars disrupt a previously large 2-component trading zone, the unified market zone often disintegrates into separate regional 2-components connected by monopolistic cutpoints. Further, in this situation, the volume of exchange both between and within regions declines, along with general economic prosperity. An example is the severe reduction of trade along the multiconnected Silk routes linking Europe to East Asia as the Mongols withdrew their protection of trade to concentrate on the conquest and then the administration of China.

These tests and the general hypothesis about the effects of k-cohesion on trade set up a dynamic that is related to the hypotheses and findings of Turchin (2003, 2006) stated above: predation or external war by growing empires across a metaethnic frontier will act to increase resistance through increases in *asabiya*, or solidarity (reflected in structural cohesion), while competition within groups, e.g., within an aging empire, will lead to decrease in *asabiya*. Both warfare on

[8] Inflation caused by excessive wars funded by the Paris royal treasury represents an exception compensated by devaluations.

metaethnic frontiers and civil wars within empires may act to reduce the structural cohesion of trading zones. These are hypotheses that Turchin has tested and found to be strongly supported.

Hypothesis set 2: Background 1. Turchin and Nefedov (2006) have examined the evidence for eight European secular cycles in the last two millennia, with lengths varying around a median of 220 years, marked by an integrative phase of population growth and a disintegrative phase of endemic conflict and population decline (Turchin 2003, 2005, 2006). The dates in Table 1 below are median dates for the lowest populations, detrended, of the largest (up to the last cycle: agrarian) polities or empires. Note that amplitudes of the detrended population cycles also vary.[9] The last three cycles shown are those of Fischer (1996). Secular cycle oscillations in population lagged by conflict are well attested in seven of these periods, with poorest fit to the secular cycle model for the German Empire cycle between the Carolingian and High Middle Ages.

Dates	*Secular Cycle (Integrative to disintegrative, lowpoint to lowpoint in population)*[10]
27BCE-285	Principate Cycle, ending with Empire in turmoil 180-285, followed by Dioclitian.
0285-0600	E. Roman Empire/Merovingian Cycle (data for dating still being collected).
0650-0900	Carolingian Cycle, ending with crises of state management and succession.
0900-1150	German Empire Cycle (Norman and German collapse, early 12th century).
1150-1450	Medieval Cycle (High Middle Ages), with crisis starting in the 14th century.
1450-1660	First Modern Cycle, ending in crisis of the 17th century.[11]
1660-1850	Second Modern Cycle, ending in the revolutionary crisis.[12]
1850-2050?	Third Modern Cycle, not yet ending in the "troubles of our times."

Table 1: European Secular Cycles according to Turchin and Nefedov (2006)

Hypothesis set 2.1. In the pre-globalization era of the Roman-Tang era and first millennium CE, long pulses of **expansion** of trade, markets, and trading networks tend to lead by as much as 100 years the integration phases of secular cycles and last nearly up to their disintegration phases. The conflicts of the disintegration phase may regionalize a **contraction** of the size of trading networks although trading volume within regions might become more intensive and extractive. Thus the next secular cycle of integration and disintegration tends, again with some time lag, to

[9] Peaks of the detrended population cycles vary in height and are lower in the first millennium than in the Roman or the Medieval cycles.
[10] Agrarian empire population cycles are detrended relative to proxy measures for food supply, e.g., bushels of grain.
[11] The three modern cycles correspond to Fischer's great waves two to four, but not as asynchronous.
[12] The Second Modern Cycle includes the Revolutionary crisis (e.g., France and America) but the Russian crisis is drawn out and occurs much later than age of revolutions.

last through the period of regionalization. *Disintegration in a regionalization period tends to act as a double negative*: disintegration of the resource and power fields of regionalized conflicts tends to allow trade to expand once again on a more global scale.

Sample test 2.1: Correspondences between a network expansion/contraction cycle and two secular cycles of population growth/decline seem to hold for the Roman period and the first millennium CE, as shown in Table 2, but the relevant data are not yet fully compiled and checked for consistence with the hypothesis. Figure 1 shows the double negative operating on a trade expansion/contraction cycle of ca. 440 years. The dashed bidirectional arrows in this graph are definitional, namely that as a disintegration phase reaches its nadir in terms of population, population can only grow from there, not diminish.

Figure 1: Operation of the Double Negative as the key to 2:1 Secular/City Size Phasing

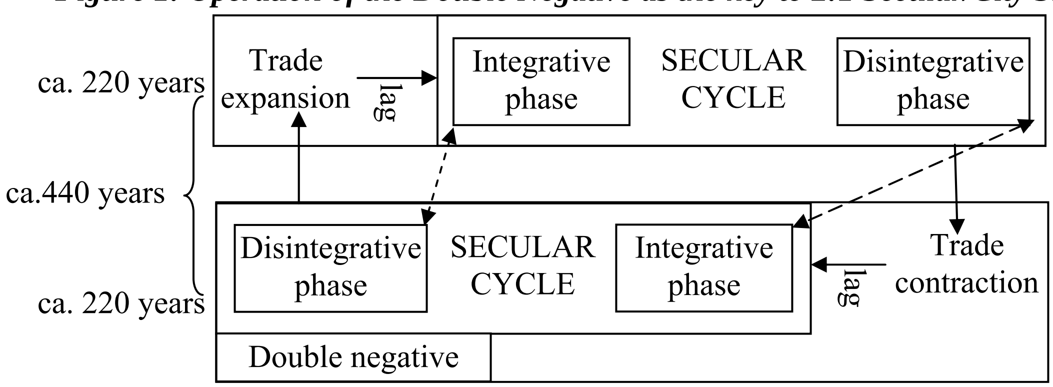


Table 2 shows the cross-correlation of lagged dates between changes in trading network sizes and the five secular cycles from 600 BCE to 900 CE.

1st Network Size Cycle, Second Half (-N2)

1st Trade Network Size: More Global N2 ca.700 market economy (<u>preceding by 100 yrs.</u>)[13]

0600-0350BCE First Roman Cycle, Axial Age.

***<u>Second Network Size Cycle (N3-N4)</u>* <u>(dates preceding by 30-100+ yrs.)</u>**

2nd Trading Network Size (Regional) N3 *<u>ca. <375BCE – <145BCE</u>*

0350-0027BCE Second Roman Cycle, Colonization

2nd Trading Network Size: More Global N4 *<u>ca. <145BCE – ?</u>*

27BCE-285CE Principate Cycle, ending with Empire in turmoil 180-285, and Dioclitian.

***<u>Second Network Size Cycle (N5-N6)</u>* <u>(dates preceding by 50+? yrs.)</u>**[14]

3rd Trading Network Size (Regional) N5 [15] ***<u>ca. <<285 – 0550?</u>***

0285-0600 E. Roman Empire/Merovingian Cycle (data for dating still being collected)

3rd Trading Network Size: More Global N6 [16] ***<u>ca. <<550 – ?</u>***

0650-0900 Carolingian Cycle, ending with crises of state management and succession.

Table 2: Cross-Correlation of Trade Network Cycles and Secular Cycles, 600 BCE- 900 CE.

The core areas of the Roman Empire were urbanized, but while the Romans reorganized settlements and outfitted them with theaters, aqueducts and other Roman accoutrements, the low population numbers in colonies and trading centers outside their core areas are rarely "urban." Urbanization thus slumps drastically with the fall of the Roman core cities and establishment of Constantinople as a new capital. At the end of the early medieval period, however, cities begin to grow once more with the influx of new trading possibilities and benefits from the Islamic trading cities that brought major innovations into Europe.

Hypothesis set 2: Background 2. White, Kejžar, Tsallis and Rozenblat (2005) scaled Western Eurasian and World distributions of city sizes in 28 historical periods over the last two millennia and found alternating long-term stability, after 900 CE, of two city distribution patterns. To differentiate the two patterns, we refer to global hubs as cities at the upper end of the size

[13] Although McEvedy (1967:54,70) shows the growth from regional trade (p.54) in 375 BCE to more global trade (p.70) in 145 BCE, trade and movement of goods in the earlier period was facilitated in a broader region by the highways built by Persians from the Persian Gulf to the Mediterranean (Westermann 1956: 14); after 350 BCE it would seem that the conquests of Alexander and later conflicts between Rome and Carthage (1956: 26-27) imposed conflict boundaries more disruptive to trade, although this has yet to be verified.

[14] Roman ostentation in consumption became so great before the Dioclitian collapse became so great that the gold drain to India and high payments for Silk road goods had several constricted the volume of trade.

[15] McEvedy (1967:88) shows disruption to trade once again, and failure of Roman finance.

[16] Westermann (1956:50-51) shows the more global trade networks of the 7th and 8th centuries, including Islamic as well as European expansion of trade, the latter responsible for introduction of many innovations from the Middle East and Asia.

distribution, in which there is a power-law tail. The slope of this tail varies in the alternating periods, from "thin-tailed" Zipfian distributions (steeper slope) to "thick-tailed" distributions with lower power-law slope coefficients. The difference in slope has implications for whether the average city has routes to other nearby cities that are relative or "neighboring" hubs, that is, nearby cities larger in size. In these terms, then, the two types of periods are: (1) rise and relative stability of global hubs, or thin-tailed distributions, with a majority of cities lacking significant local hubs, giving way eventually to the decline of global hubs at the end of the period, and (2), in the absence of extreme global hubs, that is, with thick-tailed distributions, rise in the likelihood of "local hubs" within the neighborhood of each city; eventually giving way to the rise of global hubs and the end of the period. Thus, moving up the size hierarchies, the urban distribution cycle is described by alterations between:

(1) Relative Local Equality (RLE) of city sizes rising in a "thin-tailed" urban size distribution to contrastive global-hub cities and constituting more normal Zipfian sizes.

(2) Continuous Neighborhood Hierarchies (CNH), "thick-tailed," with relative hubs likely in adjacent-city neighborhoods at the lower end of the size distribution, rising from local up to the largest hub cities which are not so extremely differentiated from the rest.

Figure 2 shows the scaling of the "thin tailed" (RLE, more Zipfian) city size distributions, and Figure 3 the scaling of "thick tailed" (CNH) distributions. There are three historical periods represented in each figure, although the RLE distributions are more distinct in each period. The RLE distributions represent the "global network" periods with "global hub" cities, but the differential banding of the RLE distributions represent the growth that occurred in the CNH periods. The greatest growth, however, occurs in the latest, RLE period. The "q" in these figures refers to the method of scaling, which is a (q-) stretched exponential that fits the entire distribution, not simply the power-law tails.[17]

[17] See, for example, White, Kejžar, Tsallis, Farmer and White (2006).

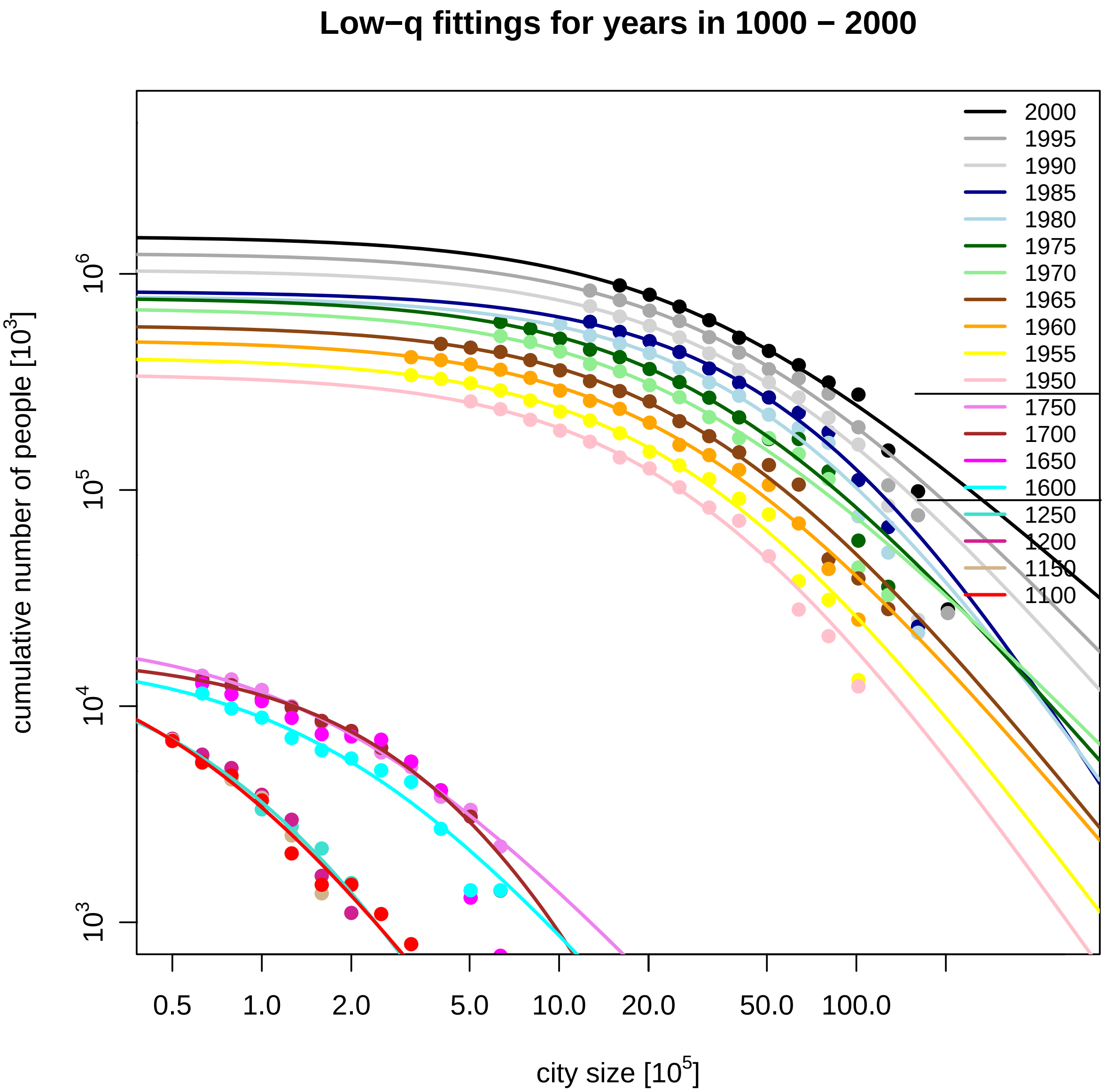


Figure 2. City Size Scaling for the "thin tailed" (RLE) city distributions in the second millennium (1000 to 2000), using nonlinear least-square (NLS) fittings. City size bins are in units of 100,000.

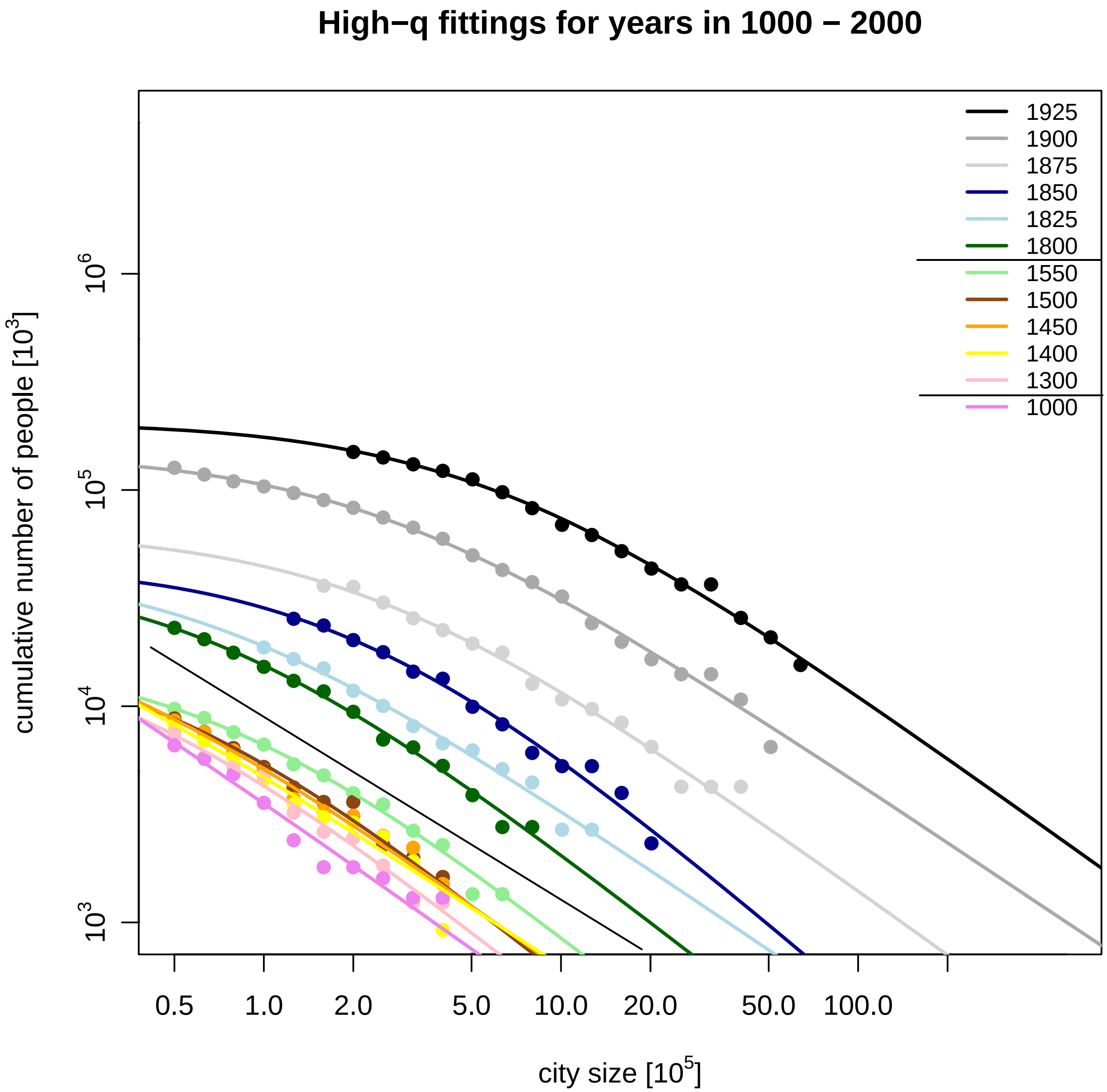
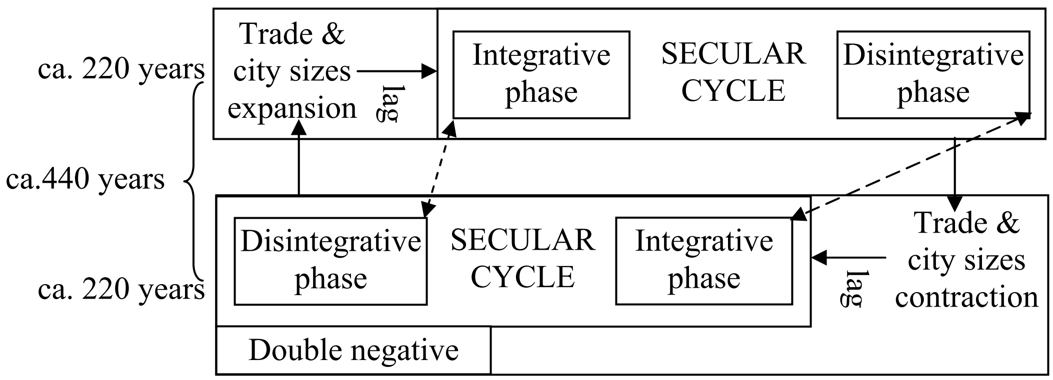


Figure 3: City Size Scaling for the “thick tailed” (CNH) city distributions in the second millennium (1000 to 2000), using nonlinear least-square (NLS) fittings.

Hypothesis set 2.2. In the globalization era of the second millennium, expansion and contraction of trade tend to operate as in the previous millennium, alternating between more global trade networks and more regional trade networks. The difference is that now these tend to be **networks of cities** rather than trade networks with relatively few core cities of polities or empires, as in the previous epoch. Again, long pulses of expansion or contraction of trade, markets, and trading networks tend to lead by as much as 100 years to integration phases of secular cycles and last through their disintegration phases. But in addition, city size distributions change between one network pulse (expansion or contraction) and the next. The same logic of the double negative applies as to why a period of regional or contracted trade networks and city size distributions, when combined with a secular cycle that ends in a disintegrative and weakened state, reemerges into a period of expansion of trade networks and more globalized city size distributions.

Sample test 2.1: The correspondences between city size distribution phases and a secular cycles, attested for the last millennia (900–2005), are shown in Figure 4 and summary data in Table 3.

Figure 4: Operation of the Double Negative as the key to 2:1 Phasing



First Urban Size Cycle (Q1-Q2)

***First Urban Size Semi-Cycle Q1 ca. 870? - 1120* (end preceding by 30 years)**

First CNH Urban Size Distribution (**Regional**)

0900-1150 German Empire Cycle (Norman and German collapse, early 12th century)

***Second Urban Size Semi-Cycle Q2 ca. 1120 - 1350* (preceding by 30-100 years)**

First RLE Urban Size Distribution (**More Global Trade Network)**

1150-1450 Medieval Cycle (High Middle Ages), with crisis starting in the 14th century.

Second Urban Size Cycle (Q3-Q4)

***Third Urban Size Semi-Cycle Q3 ca. 1350 – 1560* (preceding by 100 years)**

Second CNH Urban Size Distribution (**Regional)**

1450-1660 First Modern Cycle, ending in crisis of the 17th century.

***Urban Size Semi-Cycle Q4 ca. 1560 – 1850* (preceding at startup by 100 years)**

Second RLE Urban Size Distribution (**More Global Trade Network**)

1660-1850 Second Modern Cycle, ending in the revolutionary crisis.

Third Urban Size Cycle (Q5-)

Urban Size Semi-Cycle Q5 ca. 1850 – ?

1850-2050? Third Modern Cycle, troubles of our times (**Globalization)**.

Table 3: Cross-Correlation of City Size Cycles and European Secular Cycles

City size distributions within much reduced trading zones tend to show fewer extremely large "global system" hubs in the size distribution (even if aggregated over the entire world rather than within the smaller trading zones).[18] Concomitantly, however, there are more "local hubs" within the neighborhood of each city in the regionalized trading zone.

Hypothesis set 2.3.1. The betweenness centrality (Freeman 1979) of a city in a trade network is computed as a ratio of the shortest paths (geodesics) between all pairs of nodes in a network compared to those that pass through a given node, i.e., the city in question. Naturally, longer geodesics are less likely to be mediated by any given node than shorter geodesics, so that betweenness centrality is dependent on local regional centrality, not position in a global network structure. <u>In historical periods of protracted conflict, disruptive to long-distance trade, greater commercial profits tend to accrue to cities with higher betweenness centrality measured within the regional structurally cohesive trading zone</u>.

Sample test 2.3.1: In Medieval Europe, during protracted conflict periods for some time after 1290-, we find greatest commercial profits accruing for Genoa, as shown as the largest node in Figure 5. and which has the highest regional betweenness centrality in the trade route network.

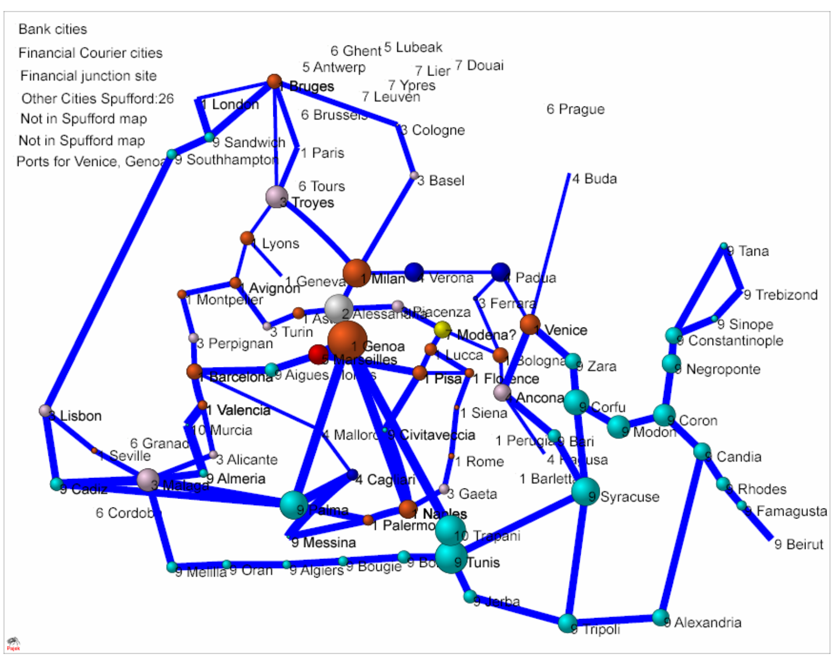


Figure 5: Genoa as a commercial center with high beetweenness centrality

[18] The initial study by White, Kejžar, Tsallis and Rozenblat (2005) is replaced with White, Kejžar, Tsallis and Tambayong (2006) as this study progresses.

Hypothesis set 2.3.2. In historical periods of protracted conflict, operating in more restricted areas of trade, the need for long-distance credit mechanisms is minimized, and thus the pressure for developing banking centers is reduced. Capital accumulation is thus somewhat more likely to take a commodity form, accumulating productive physical wealth, rather than monetary form through institutions of credit and banking.

Sample test 2.3.2: Detailed support for this hypothesis is given elsewhere for data summarized by Spufford (2005). Spufford also shows that centers of finance capital tend to persist long after a city's centrality declines as a commercial center, so finance capitals will persist beyond the periods in which they originated.

Hypothesis set 2.4. Flow centrality for a given node in a network is the reduction in the total of pairwise flows between nodes that occurs after the specified node is removed from the network (Freeman, Borgatti and White 1991). It is dependent not on shortest paths, but pairwise flows within the entire network.[19] In historical periods of more global long-term structural cohesion conductive to longer-distance trade, greater financial profits and capital for reinvestments accrue to cities with higher flow centrality, measured within the global structurally cohesive trading zone.

Sample test 2.4: In Medieval Europe, during the periods of more global trade networks,[20] we find greatest financial profits in cities that have the highest (global) flow centrality in the trade route network. For 1123-1299, for example, this is true for Venice (i.e., after their defeat of competing Arab fleets) but the Venetian advantage erodes in subsequent times of disruptive conflicts (e.g., their naval defeat by Genoa in 1299). High levels of flow centrality for cities in the Netherlands predict, with a long time-lag, the eventual emergence of Amsterdam as a profit center. In Figure 6 Bruges is the node with highest flow centrality (nodes are scaled in size according to centrality

[19] The flow between a pair of nodes in a network is computed by considering the flow capacity of distinct paths between the endnodes (each containing at least one different edge) to consist of the minimum capacity of any of its edges. Then the maximum flow has been proven equal to the minimum sum of capacities on any set of edges whose removal disconnects the two endnodes.

[20] Regionality or globality of trade, or size of trading zones, are measured by existence of long-term structural cohesion (2-component at minimum) in routes connecting cities that are conducive to long-distance trade.

levels, as in Figure 5).

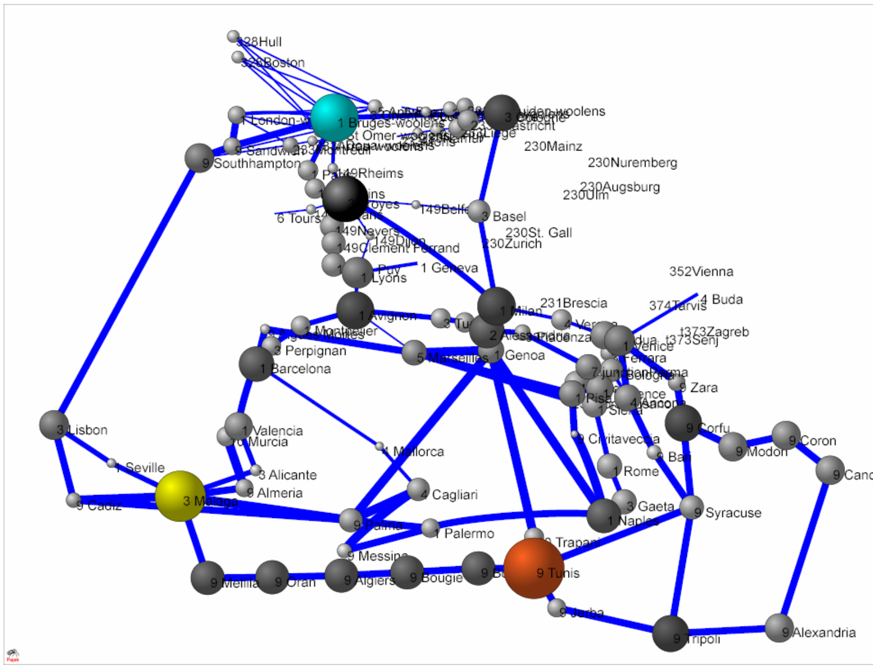


Figure 6: Amsterdam as a financial center with high trade flow centrality

Hypothesis set 3.1. Historically, in all urban societies, elites constitute one or more social classes (or sometimes castes) that are constituted in terms of their degree and types of rights over and inheritance of resources as defined by structural endogamy. Structural endogamy is a special case of structural cohesion in which the relevant relationships producing cohesion are those of marriage, descent, and adoption.[21] Elites in chiefdoms and kingdoms, not necessarily urban, differ in the typical composition of the endogamy that gives them kin and marriage-based structural cohesion. Based more exclusively on military power rather than urban manufacture and centralized control, these elites typically embed a greater portion of their control and transmission of resources on a combination of strategic marriages and marriages within kingroups sharing common descent or fictive political genealogy. These forms of structurally endogamous cohesive kinship networks thus tend to have both alliances between descent groups and marriages within them, i.e., marriages between blood kin.

[21] Technically, to capture structural endogamy, marriages are taken as nodes of a network in which the lines are those of descent (sons vs. daughters back to their parents). Then the unit of (maximal) structural endogamy is the 2-component in which every couple has two or more node-independent paths to every other couple. This means that every person has not one but two or more relationships with every other, and either every marriage is with some kind of relative or at least one person in every marriage provides a descent links between two such marriages. Blood and marriage alone allow only 2-components, but the addition of adoptive links makes possible cohesive 3-components.

Sample test 3.1: In the European Medieval period, we see the growth of new institutions of sovereign states, along with new ways of running rural estates, building specifically on Roman precursors and legal concepts of sovereignty. Limited regions, such as the core polities of the former Merovingians and successor Carolingians, form the seed of French Sovereignty over territory and office. New ways of running rural estates, building specifically on elements of the defunct Roman latifundia, include the breakup of extended families among subordinate peasantries and communal housing that emphasizes, in the new context of Christianity, the sacral importance of the married couple as a basic unit of accountability and responsibility for offspring. In contrast, in other regions we see varieties of classical German and Frankish (and in some cases Scandinavian) kinship, originating outside the Roman systems of sovereign law, based on the notion of partibility of inheritance and the right of each son (or in some cases daughter) to inherit a division of property. The forms of kinship and inheritance tend to influence a great many other political and social institutions, including the ways that polities were constituted and divided. In the chieftain type of polity, the accession to unitary power of a leader who conquers territory or adds territory through strategic marriage or inheritance is dissolved on the death of the leader. In its extreme hierarchical forms, however, we see transmutations such as the predatory kinship described by Searle (1988) for the Normans, transformations that lead to a predatory state-like hierarchical structure that spread through conquest, after Normandy, first to England, and then through Angevingian successors the Normans, to Sicily and Naples. These conquests had powerful effects on subsequent conflicts, such as Norman English/French conflicts in the lowland countries and France, and Angevin/German conflicts in Southern Italy. The conflicts of hierarchical and predatory state-like Norman kinship-based polities, in this aggressive and expansionary form, had massive effects on destabilizing land-route trading in Europe as part of the 14th century declines.

Hypothesis set 3.2. Until the advent of the written will, which is comparatively recent and possible only within a type of state sovereignty in which the overarching institutions of sovereign justice of the state overrule those of customary law, claims over the property of kin, either at marriage or when kin are deceased, operate as potentially binding claims subject to strategic supports within kinship or structurally endogamous groups. Strong kinship ties thus provided powerful and at times very cohesive networks (and not only in Europe), controlling intra-familial flows of resources, and sometimes relationships of trade.

Hypothesis set 3.3. For the emergence of polities, then, many of which even today in less developed parts of the global civilization are constituted by clans rather than sovereign states, it pays to look at the varieties of networks (VoN) as emergent forms that come to occupy specific cultural regions, and where local customary practices that tend to be binding on customary law subject to political strategies and struggles within cohesive but potentially contending families produce particular cultural, political, and economic effects. The forms of cohesive bonding also affect the scalability of groups so as to recruit greater numbers of members or recruits when challenges or external conflicts arise.

Sample test 3.3: The growth of political sovereignty occurs in remnants of intact fragments of Roman states sovereignties of the north Italian city-states and the French domains extending from Soissons through Paris to the Loire. These areas, when compared over time, show different evolutionary paths, but leading to varieties of modern sovereign state authority (VoA). A study of these processes and timelines would have to depend heavily on analysis of contending aspects of networks operating through customary law (kinship, inheritance, and family succession) versus territorially sovereign legal institutions.

Hypothesis set 4.1. A key element in civilizational dynamics is the strong tendency toward conservation of connectivities –routes and modes of travel and communications – in spite of the rise and fall of polities and empires, or of the elites that sustain their industries, innovativeness and governance. Networks are so central to human life and the sustainability of civilizational interactions that they are often preserved or reconstructed, even if in reduced form, even after the demise of sets of many of the cities, states or empires co-responsible for their development. This entails that to a large extent the technologies and transports of the past are to a large extent maintained or surpassed as an element in civilizational continuity, so long as cities continue to exist and trade. The negative case for this argument is the European demise of cities as a principal form of settlement following the Roman collapse and the consequent decay of the Roman road system.

Hypothesis set 4.2. Diffusion and adoption of innovation, occurring from place to place, does not occur equiprobably in all directions, or across what Turchin defines as metaethnic boundaries that separate wholly different ways of doing business and culture. Here, of course, the difference in network types and histories (VoN) is in play once again.

Sample tests are perhaps not always needed for these last two hypothesis sets, which state some of the different but ubiquitous features of civilizational networks. Korotayev (2006) reviews the argument in 4.1 and 4.2 along with relevant evidence for the innovation and conflict phases of Turchin's secular cycles.

Putting together the Dynamics of Civilizational Networks

Turchin and others have elucidated some of the potential factors shaping the rise and fall of empires, polities, and civilizations. Incorporating network theory into an account of civilizational dynamics in Medieval Europe, in relation to the Near East and Asia, involves an integration of elements of various theories:

- VoS, e.g., varieties of world historical systems theory,
- VoC, varieties of capitalism (e.g., commercial versus financial),
- VoN, varieties of networks (capitalist and pre-capitalist; organizational forms of network linkage and bonding[22]), but also an expansion of
- Modelskian (Modelski and Thompson 1996) long-waves theories and
- an even slower scale of morphological oscillations of urban systems impacted by fluctuations in the structural cohesion levels, boundaries, and overlaps of trading zones, in turn affected by oscillations in global patterns of trade, war, invention, diffusion, and conservation or retention of urban innovation as well as transformation of systems of production. To these we must add

[22] Linkage describes the pattern of topology of links; bonding the particular way in which links concatenate dynamically in how a network scales up or down in size by recruitment of sloughing off of members.

- Turchin's (2003, 2005, 2006) cycles of rise and decline in the cohesion of polities, in the secular cycles of overpopulation leading to civil strife within polities, and the father-son generational delays in repetition of civil wars.

An integration of these component theories would deal with how these factors shaped and reshaped specific parts of world historical networks, at a variety of time scales.

Europe has no special warrant for uniqueness: centers of economic innovation and leading polities rotate about the globe, with political hegemony usually emerging out of leading sectors and places of economic innovations, as inventoried by Modelski and Thompson (1996). The Sung built on the technologies of previous empires that for millennia developed in the context of defending successfully against cohesive external enemy to the north. The early Chinese and Sung technologies often took close to a millennium to diffuse to Europe (Temple 1987). The Sung in their time developed national markets and systems of credit capable of extension over multiconnected trade routes such as the Silk Roads and maritime trade. These trade multiconnectivities in the long periods of relative peace raised the economic prosperity and inventiveness of many cities over the whole of Eurasia. The late medieval phase of Eurasian decline occurred as the Sung lost status as the core world-system polity as China was overtaken by nomad expansions (produced more specifically by local conflicts with other Chinese groups that led to two successive invitations from the Sung to help curtail their local Chinese enemies, eventually leading to the conquest of China by Mongols and the Mongol assimilation to forms of Chinese state governance and empire, with loss of considerable innovativeness and decline of external trade). In the era of these nomad expansions were the Norman/Angevin and other predatory invasions in Europe. Both processes, at either end of Eurasia, contributed to disrupting the multiconnectivity and intensity of global trading. After the Sung collapse, core regions of the Eurasian world-system moved successively westward.

Within the Eurasian world historical system there have been alternations between forms of capital in core cities, between financial and commercial forms, and as cores rise and fall and their transformations affect semi-peripheries and peripheries. It is helpful if we try to shift from quasi-functional typologizing and comparing empirical cases to ideal types, as in VoC theory today, over to understanding the interaction of different processes, as in VoS or world historical systems theories and models. The latter, however, often go too far in generating models on the basis of prior assumptions and partial observations, rather than testing of alternative hypotheses more systematically, based on more realistic mapping of the interactions occurring within historical processes. Incorporating network theory adds new dimensions to theory and to testable hypotheses. We can specify generalizable structural properties that are comparable from case to case, relation to relation, and incorporate how relations, entities and levels of emergence became historically embedded in one another, tracing structural changes through time along with bundles of events that precipitate change. Recasting processual data in terms of longitudinal network representations and mappings is not such a difficult analytical problem if the fundamental framework of the representations is conceptualized in ways that allow testing of hypotheses about observable processes and changes. And above all, if, by specifying observable interactions that might be represented in ways that include network processes, they allow different models of the dynamics of interactions—what drives what—to be tested.

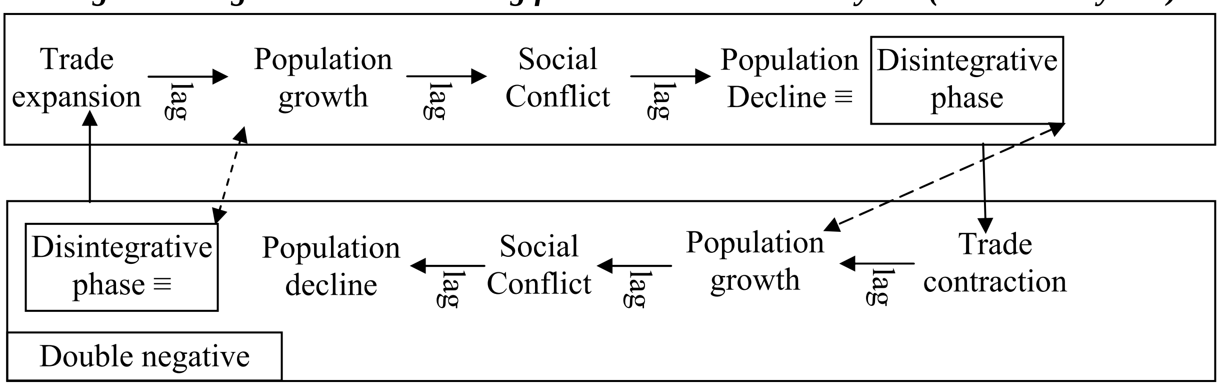
Also interesting in the study of Europe and the Near East are the many types of precursors of modernity that can be studied in network and flow models. These include study of the emergence of modern prototypes of capitalism, with the profit-oriented variety being more familiar, but with commodity capitalism recurring at various times and places throughout the medieval and modern eras. Various forms of contract, corporation, and credit mechanisms come into Europe from the Near East in the Medieval period and presage in many instances a variety of modern forms of corporations, banking, and credit. Near Eastern forms of banking, like *hawali*, operating through nonstate, nonofficial, and noncorporate networks, under the radar of formal sovereign states, remain today as in the Medieval period and are as potent a form of mobilizing and transferring credit for exchanges as the formal banking and state-regulated sector.

To be sure, a long period of depression, including what we call the Renaissance, separates the Medieval 13th century "Early Renaissance" from the world economy of modern states, for which leading polities have perfected the mechanisms of sovereignty. But from one perspective, while the quantitative balance between sovereign states and clan or kinship polities (see for example, Collins 2006, White and Johansen 2005) has shifted from Medieval to Modern, both are present in both periods and both are part of civilizational dynamics.

Implications for Dynamical Modeling

What is new in this reasoning about the findings of how two of Turchin's (2003, 2005, 2006) secular cycles of population growth/decline (integration/disintegration) fit into one trade network expansion/ contraction cycles (or city size globalized/localized hierarchy cycle) is the role of the double negative: The combination of a disintegrative secular phase and a contracted network regionally constrained by polity conflicts at the borders of region seems to be sufficient to weaken the border-polity conflicts, and clear the way for more globalized trade patterns to reemerge after being long suppressed.

Figure 7: Lag times in 2:1 Phasing for Secular and Trade Cycles (ca. 220/440 years)



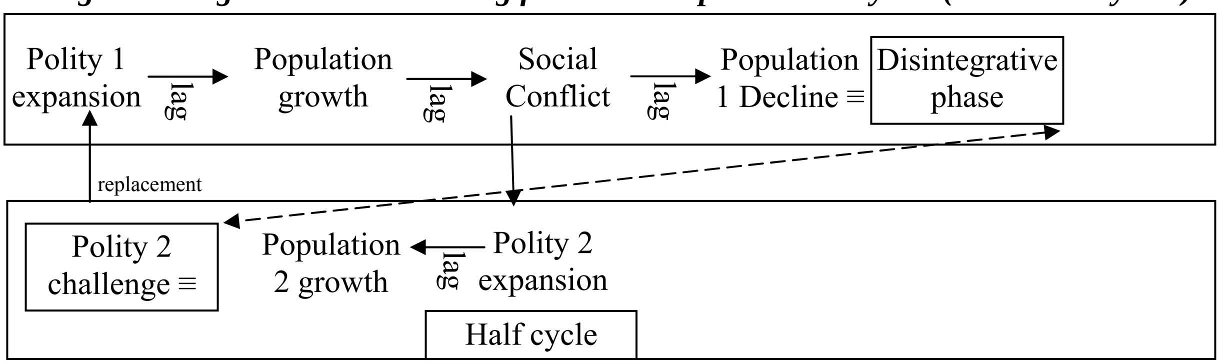
Hypothesis 5. Rather than the two lags posited by Turchin in his secular cycle model, there are three lags per trade-and-secular cycle, as shown in Figure 7. Recall that because the dashed lines in this graph represent the transition between a population nadir and subsequent growth the disintegrative phase must always be followed by population growth although the lag time may be variable.

The role of trade in population growth or decline may also vary, and is a topic to be investigated, but conceivably trade network topology and network predictions may help to clarify network dependencies in world historical system dynamics.

Reinterpreting Modelski Leadership Cycles with Double Negation

Finally, the framework introduced here for understanding how some world historical cycles are embedded in other cycles might also be used for other embeddings of cycles, such the approximate 2:1 embedding of Modelski's Leadership Cycles (Modelski and Thompson 1996) within Turchin's secular cycles. Figure 8 shows how challenges to leadership might nest into the double negative model of Figure 7, but this time occurring at the half-cycle in secular oscillation, a time at which the leading polity is weakened by social conflict. Similarly, "halfway" through the polity expansion cycle (although temporally variable) is the population growth phase that might couple to leading economic sector growth for a leading polity.

Figure 8: Lag times in 2:1 Phasing for Leadership / Secular Cycles (ca. 110/220 years)



Conclusion

At the foundation of a rethinking in a network perspective of long and convoluted world historical systems change[23] (e.g., Denemark, Modelelski, Gills and Friedman 2000) is a compelling need to study dynamics in terms of specific interactions, the ebbs and flows of differential network histories that nonetheless can be seen to operate in large part under some set of generalizable processes. Network theory can clarify basic concepts that can be used to test specific interactional hypotheses derived from principles that are both very general, but also specifically tailored to the phenomena at hand.

[23] I distinguish change, define in terms of observations from longitudinal studies, from dynamics, which is causative explanation of change (see White and Johansen 2005).

If the reasoning of this paper is correct, then a speculative hypothesis is that a network approach to world historical systems, coupled with other theoretical frameworks, offers a series of supplemental hypotheses and potential explanations for historical change that are very specific regarding the channeling of change and that take different network contexts into account. The speculation is that with additional understanding of network predictions and explanations of network and historical dynamics, we should find that what have been taken as idiosyncratic "path dependencies" will to a large extent turn out to be network independencies, subject partly to the role of agency, but much more predictable than previously thought possible.

Finally, because the longest-term observable pulses in the world historical system in a composite model of all the hypotheses presented here are those toward or away from more global networks of trade, this theory contains an answer, not fully investigated as yet, as to why we observe the synchronization of secular cycles and changes in city size hierarchies as between west and east Eurasia, but not south Asia (Chase-Dunn, Manning and Hall, 2000; Chase-Dunn et al.). The explanation is that once trading networks of one macro region interconnect with those of another, i.e., where one or both are sufficiently expanded to do so, then the two economics and their secular cycles have a potential to synchronize that was not present previously, and that need not involve other regions that remain disconnected.

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