Lessons from Population Ecology for World-Systems Analyses of Long-Distance Synchrony

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INTRODUCTION:

In this chapter we have several objectives. First we observe that many processes within world-systems are often characterized by cycles or waves – chiefdoms cycle, empires rise and fall, and the modern state system undergoes "power cycle" or "hegemonic sequence." Furthermore, all world-systems "pulsate" – expand rapidly, then more slowly, or even contract (Chase-Dunn and Hall 1997; and Chapter 5). Because spatial waves of expansion/contraction occur across all types of world-systems, such pulsations cannot be rooted in a specific mode of production or mode of accumulation. Rather, these cycles are themselves evidence that polities and world systems are dynamical systems with various feedback loops. Second we want to explore the issue of spatial influences and how those interact with various social factors in world-systemic processes, especially the synchronization of cycles across great distances. Third we suggest some potential empirical tests of these models, and that whether or not these models work the exploration of them will deepen our understanding of social evolutionary processes. Fourth we argue that this is not an exercise in reductionism, nor is it an attempt to remove actors form the system. Rather, it helps sort how structures change, how they constrain behaviors, and conversely, how behaviors can act on those evolutionary processes.

Following Butzer (1997), if there is any systemness to a system, changes should permeate through it. Rephrased somewhat, cycles **are** evidence of some sort of **system**. Previous research has shown that there is a broad degree of synchrony between the sizes of empires and city populations in Europe, West Asia, and East Asia (reviewed in Chapter 5). By contrast, Indic empires are far less correlated with the other Eurasian regions. A similar pattern is observed in population dynamics. Figures 5a and 5b in Chapter 5 show the populations of the four Eurasian macroregions (taken from McEvedy and Jones 1978). There is an increasing trend affecting all population trajectories, which is presumably a result of socio-cultural evolution. We are interested in the fluctuations around the trend, and therefore we have detrended all series by the technique known as "differencing" (Box and Jenkins 1976). When log-transformed population data are differenced, we obtain relative population growth rates. Focusing on the growth rates during the better studied period of 800 – 1800 CE we observe that all regions except for South Asia appear to fluctuate in synchrony (Figure 1b). In fact, the degree of synchrony apparently increases towards 1800.

These data are very "noisy," so the findings **may** be an artifact of the data. However, the patterns hold with various refinements which strongly suggests that these theoretical and empirical issues are worthy of further investigations: (1) that there are cycles in populations, city sizes, empire sizes, etc. (not all these are shown here); and (2) that there is some correlation, or synchrony between and among East and West Asia, and less with South Asia. This latter echoes that made by Teggart (1939).

The other world-systems puzzle is that Afroeurasia has been linked, at least at the information and luxury goods exchange levels (Chase-Dunn and Hall 1997), for two and half millennia or more. Thus, events and processes in Europe cannot be explained solely by examining European processes, a conclusion strongly supported by Pomeranz (2000). On the other hand, the degree of Afroeurasia-wide linkage fluctuated, so that world-systems at opposite ends of Afroeurasia were nearly isolated for long periods of time. One aspect of this puzzle is why these rise/fall processes at the western and eastern ends of Afroeurasia have been linked during the last two millennia (reviewed in Chapter 5). For example, increases and decreases in the territorial sizes of empires and the population size of cities correlate between East Asia and West Asia-Mediterranean, yet, there appears to be little linkage to cyclical processes in South Asia. Interestingly, archaeologists have noted seeming parallels in rise and fall of ancient cultures in what is now southeastern and southwestern United States (Neitzel 1999).

There are at least three sub-issues here: (1) why these instances are east – west and not north – south; (2) why there are cycles; and (3) how those cycles become linked, especially over great distances. As a beginning working hypothesis we suggest that Diamond's thesis is applicable. Given similar environments, or biomes, similar kinds of social systems may be in evidence along an east – west axis. If those systems are characterized by, or include, cyclical processes, what are phase relations among their various cycles? Do some cyclical systems become linked – phase-locked or phase-shifted? Or do they oscillate independently? The questions are how and why? Our third point is that once analyzed and described, these linkages can be subjected to more rigorous testing.

One very interesting finding from animal ecology is that the certain types of synchronization of predator – prey cycles actually produces rapid evolution with prey populations as direct response to the synchronous linking (Turchin 2003a). In other words, the linking, or synchronization, of cycles can itself be a mechanism of evolution that pushes social change in predominantly one direction over another.

We want to assert two caveats here. First, we are not being teleological. Rather, we are claiming that under certain circumstances some results of change are far more likely than others. This should lead to questions about the roles of agency and/or praxis in social change. It should also lead to questions as to what other alternatives might exist. It may also help us better understand how and why the result of intended change can lead to unexpected results, such as in the French revolution, the revolution of 1848, or the Russian revolution.

The second caveat is that we can not simply map biological models directly on to social processes. Social evolution tends toward convergence, whereas biological evolution tends toward divergence (Sanderson 1990). These caveats and data problems notwithstanding, we argue that we can learn much about social evolution by exploring and applying these models.

We begin with a review of population ecology.

WHAT THE ECOLOGICAL THEORY SAYS ABOUT SYNCHRONY

Ecologists have long puzzled over why many oscillatory population systems exhibit large-scale spatial synchrony. Charles Elton (1924) speculated why lemming peak years should be synchronized across much of Norway. He also observed that the ten-year lynx cycle is synchronized over the whole taiga region of Canada in Hudson Bay Company data on lynx pelts.

P.A.P. Moran developed statistical approaches for analyzing such synchrony and proposed a formal mechanism to explain it, known in the ecological literature as "the Moran effect" (Moran 1953; Bjornstad 1999). The idea that synchronized exogenous shocks to local oscillating systems will cause them to come into synchrony even when the exogenous shocks do not themselves display much periodicity (Ranta, et al 1996; Ranta et al 1999). A key issue was determining which mechanisms may cause synchrony.

Synchronizing mechanisms

Ecologists have classified mechanisms that induce spatial synchrony along two continua: exogenous versus endogenous and local versus "global." A factor X is called an exogenous mechanism if it is not part of the feedback loop: X affects the variable of interest, while the variable of interest does not affect X. By contrast, an endogenous factor is one that is part of a feedback loop: the variable of interest affects X and then the change in X effects the variable of interest. Of course, we do not always (or even often) know all the feedback loops that affect the dynamics of the variable of interest. Thus, in practice, we call endogenous only those mechanisms whose feedback influences are explicitly taken into account (e.g., modeled). For example, in human-dominated ecosystems the usual assumption that climate affects population, but population does not affect climate, does not necessarily hold. Chew (2001; see too Chapter 5) shows that early human civilizations so denuded forests and salinized agricultural land that they may, indeed have changed local, if not regional, climates. Some of these changes may be system-wide. Thus, some climatic changes may need to be modeled as endogenous, rather than exogenous processes.

Ecological theorizing uses the terms "local" and "global" in differently from their usage in world-systems analysis. A "local" mechanism is one whose effects fall off with distance. By contrast, a "global" mechanism affects all points in the relevant space similarly, without any regard to how far these points are from each other. Thus, "global," in ecological literature might be glossed as "system-wide" in world-system analysis. For clarity, we use "planetary" when we mean the entire world, and "global" only in the ecological sense.

Given these two dimensions (endogeneity and locality) we can define four regions of a universe of potentially synchronizing processes (see Figure 1, for more detailed explication see Turchin and Hall 2003). Ecologists have tended to concentrate on two: the global exogenous and local endogenous mechanisms. The most discussed global exogenous factor in ecology is climatic variation. It is a quintessentially exogenous process because variation in temperature and rainfall can have a very strong effect on survival and reproduction of organisms, while fluctuations in organism population numbers almost never have an effect on weather (although for humans this is not necessarily true).

In any case, close examination of specific mechanisms shows that the global-local distinction defines a continuum, and not a dichotomy. For world-systems analysis, given the potential effects of human activity on climate (see Chew 2001, Chapter 7), clearly "global" or system-wide mechanisms would be a massive volcanic eruption or collision with a sizable comet. Alternatively, if there is a truly exogenous climatic shift (due, say, to sun spot cycles or some such mechanism that humans could not affect) and if it were planetary, then we should see global synchrony, across Afroeurasia, Meso- and South America, Southeast Asia, and sub-Saharan Africa. This would still require some subsidiary explanation for the already documented lack of synchrony in South Asia.

The quintessential local endogenous mechanism is movement. It is endogenous because the number of organisms spreading from a source depends very much on the population density at the source. It is local, because organisms do not "teleport." Rather, the density of dispersers declines with the distance from source. We note that movement may also refer to other components in the dynamical system, such as predators or pathogens. Socially, disputes in family succession among elites, as among Mongols who had competing lines of succession (laterally and lineally) would be examples (Barfield 1989; Chase-Dunn and Hall 1997: Ch. 8). Rules of succession or descent vary by cultural group, and thus are typically localized. Such rules do change, but usually only very slowly, often pushed by changes in the ecology of production and adaptation. Under certain circumstances movement may be exogenous or global or both. Movement would exogenous when the area is subjected to recurrent invasions of predators or pathogens. Finally imperial policies might be an endogenous global factor, for instance, the wide-spread effects of the Roman Empire on its various frontiers.

Types of oscillatory dynamics

The efficacy of different mechanisms described above to synchronize oscillations depends on the nature of the dynamics characterizing the synchronized systems. The key distinction is between stable and chaotic oscillations. Chaos is defined as bounded oscillations with *sensitive dependence on initial conditions* (Eckman and Ruelle 1985). The faster trajectories diverge, the more sensitive to initial conditions (and therefore the more chaotic) the system is.

The same argument applies to the behavior of two identical or very similar systems. If their dynamics are stable, then the two systems starting from similar initial conditions will tend to oscillate in synchrony. Small random perturbations will keep them out of perfect synchrony but the stable nature of the two systems will act to bring the two trajectories back in synchrony. By contrast, two identical chaotic systems starting even from very similar initial conditions will rapidly diverge and oscillate asynchronously (the “butterfly effect”). Small random perturbations will make this process of divergence even faster.

In general, exogenous drivers are not powerful synchronizing mechanisms. A substantial degree of spatial synchrony requires, first, that local dynamics are stable (nonchaotic) and second that the exogenous factor acts globally (is system-wide). The Moran effect (see Chapter 5) is the mechanism of entrainment.

Endogenous factors such as movement have a greater potential for inducing spatial synchronization, especially where cycles are stable. Ranta et al. (1998) showed that even relatively low rates of movement can induce a near-perfect synchrony of locally cycling populations. This property of nonlinear systems is called phase-locking (Bjornstad 1999). However, systems with locally chaotic dynamics will remain uncorrelated by movements.

Summary

A few themes emerge from this review. First, spatial synchrony is promoted when two local systems are driven by similar dynamical mechanisms. Second, processes that act globally (that is, on a system-wide basis) promote large-scale spatial synchrony. Third, the type of local dynamics affects very much whether any particular mechanism will induce synchrony. Systems with stable oscillations can be synchronized over vast geographic distances by global exogenous influences. Fourth, endogenous factors such as movement may result in a very high degree of synchrony – phase-locking, but the spatial extent may not be great, because the effect of movement attenuates rapidly through space. Additionally, endogenous processes may cause out-of-phase cycles. Fifth, chaotic systems are very difficult to synchronize either by exogenous or endogenous mechanisms. Only global catastrophes that reset all locations to approximately the same initial conditions can impose some (fleeting) degree of synchrony on chaotic systems. Examples include events such as collision with a large comet or a massive volcanic eruption.

IMPLICATIONS FOR WORLD-SYSTEM RESEARCH

East-West synchronicity and global climate

Ecological theory suggests several hypotheses synchronous changes of empire sizes in West and East Afroeurasia, the simplest one being the effect of an exogenous global factor – climate. World-system theorists (see Chapter 5) have already suggested this explanation. In a study of historical demography Galloway (1986) shows that populations of Western Europe and China increased and decreased roughly in parallel with solar activity.

Another explanation might be the long term effects of the Mongol conquest and empire which briefly connected East and West Asia, but also started a series of remarkably coherent oscillations in Central Asia and adjoining regions. The huge territory conquered by the Mongols during the early 13th century which were ruled by four separate Chingissid dynasties. According to Turchin (2003b: Chapter 7), these four polities should be subject to the Ibn Khaldun cycles of around a century.

The Ibn Khaldun cycle, named after the 14th century Arab sociologist who first described it, is a variety of a secular wave that tends to affect societies with elites drawn from adjacent nomadic groups. The dynamics of an Ibn Khaldunian world-system are determined by the interaction between a sedentary, agrarian state and surrounding steppe or desert pastoral "tribes." The sedentary state region is the site of recurrent state building/collapse episodes. It is inhabited by indigenous commoner population that provides the productive basis of the society. The steppe or desert is inhabited by stateless tribes that periodically conquer the civilized region and establish a ruling dynasty there. Steppe or desert tribes, thus, supply the elites (nobility) for the sedentary state. Ibn Khaldun cycles tend to operate on a faster time scale, so that their period is about 4 generations, or a century.

This is an alternative way of viewing the analyses of Barfield (1989) and Chase-Dunn and Hall (1997: Ch. 8). As Barfield notes, however, the Mongol conquest was exceptional with respect to the usual strategy employed by the Central Asian nomads. First, the Mongols succeeded in capturing much vaster regions, due to innovations in organization by Chinggis. Second, instead of merely exploiting sedentary states, the Mongols actually conquered large empires, and then had to run them. Finally, the empire broke apart due to Mongol rules of dynastic succession that emphasized both lateral and linear descent. These extensive Mongol conquests also disrupted the Ibn Khaldun cylces, in effect resetting them in several different areas simultaneously.

Thus, the Chinggisid dynasties went through typical Ibn Khaldun cycles of about a century in period, and all experienced collapse at approximately the same time. In China, a native dynasty expelled the Mongols after one cycle, while in Russia and Iran the steppe dynasties went through two cycles before giving way to native rulers. Incidentally, the central Eurasian steppes continued to undergo Ibn Khaldun cycles, until their conquest and division between the Russian and the Chinese empires (Barfield 1989). What is remarkable is the degree of synchrony in the socio-political dynamics of the settled regions initially conquered by the Mongols in the 13th century. One possible explanation of this pattern is that an initial catastrophic event – the Mongol conquest – reset all regions to approximately the same initial conditions. Thereafter, each region oscillated as a result of its endogenous dynamics, but because oscillations were driven by similar mechanisms, political collapses occurred at about the same time.

Asynchronous South Asia

If we consider Jared Diamond's (1999) observation that absent formidable barriers, east – west movement along similar latitudes (and therefore similar climates) is easier than north – south movement that traverses different ecological zones, we can construct one explanation for east - west Asian synchronicity, and its lack with south Asia. This is all the more so, since the Himalayas are a formidable barrier to contact and exchange. While there has been extensive traffic across the Himalayas, it may not have been sufficient to synchronize the various systems. Steppe nomads seldom made incursions into south Asia. Central Asian influence on India was transmitted indirectly via the Iranian plateau.

Two additional factors give tangential support to this supposition. First, while bulk goods, large populations, and armies rarely moved between South and Central Asia, travelers and ideas did so extensively. The spread of Buddhism and of silk and other luxury goods are familiar examples. Both illustrate the critical difference between the various boundaries of world-system, bulk goods and the military-political exchanges on the one hand, versus information and luxury goods on the other (see Chapter 5). Second, south Asia had tremendous effects on southeast Asia. Again there is the spread of Buddhism, but also other cultural features, and trade in luxury goods. Yet, if the east – west vs. north – south differential is at work, there should be some synchrony between south Asia and Southeast Asia, and less synchrony between Southeast Asia and east Asia. But this remains an issue in need of careful empirical study.

A second explanation for asynchronous dynamics in South Asia is the effect of climate. A cold wet climate leading to problems in most of Eurasia might have been a boon for South Asian agriculturalists. The two hypotheses, movement (of people, goods, and ideas) and global climate are not mutually exclusive.

A possible third explanation for asynchronous dynamics in South Asia is that local, i.e., endogenous, processes may have differed significantly between south Asia and the rest of Asia. This would seem less likely, but it is a possibility that warrants consideration.

Currently we do not have sufficient data to discriminate among these explanations. Still, the arguments and analyses presented here suggest ways these issues might be addressed empirically.

Summary Thus Far

We can not simply map biological models directly onto social processes. Rather, our approach needs several ingredients for success. On the empirical side we need a more detailed database of territorial dynamics of all polities within the Afroeurasia. We also need data on spatio-temporal dynamics of other variables that may affect synchrony, such as epidemics and climate. Some databases already exist, e.g. Biraben's (1975) compilation of places affected by the Black Death in Europe and the Mediterranean. Certain kinds of data, such as climate change, are in the process of being developed (e.g., Mann 2000). Other data will probably need to be developed entirely.

On the modeling side we need a better understanding of processes that may cause oscillations and synchrony. What would be particularly useful in the study of synchrony would be estimates of the rates of movement for different "things" – goods, pathogens, ideas, and people.

Such a research program would be expensive in time and money. We argue that such an investment is warranted. Recent results that suggest sociopolitical cycles and wide-scale synchronicity within the Afroeurasia are "intoxicating" (Denemark 2000). Unraveling the complex interactions causing the empirical regularities will require sophisticated quantitative tools.

Below we present a brief example to illustrate the type of analysis and types of data needed to support them to engage in such research.

SYNCHRONY AND PHASE-SHIFTS IN SOCIO-ECONOMIC VARIABLES: AN EXAMPLE OF ANALYSIS USING DATA FROM PRE-INDUSTRIAL ENGLAND

In the previous section we have outlined our general vision of the research questions and methods of approaching them. However, we realize that some readers may not be familiar with quantitative techniques of data analyses, which have been recently developed for investigating dynamical systems, and therefore this section will provide an illustration. More specifically, we have two goals: (1) illustrate how time-series techniques can reveal synchrony and phase-shifts, and how such results can be useful in testing various mechanism-based explanations of the observed patterns; and (2) provide an example illustrating some aspects of mechanisms underlying secular waves, using data for pre-induistrial England (before c.1800). The results we report below come from Turchin (2005) and Turchin and Nefedov (2006); here we simply summarize it without going to a great depth into technical details.

We begin the analysis with data on population dynamics in England and Wales (Wrigley et al. 1997). There are two features of the data that are immediately apparent. First, there is a very long increasing trend, which appears to accelerate around 1800 (Figure 2). The forces explaining this trend are not controversial, and have to do with the English industrial revolution. The second feature of the empirical curve is the oscillations around the trend, with an average period of about 300 years. Our main interest is in the oscillations, so somehow we need to remove the trend. Detrending is best done when we have some mechanistic basis for it. In this case, we can estimate the carrying capacity of England by multiplying the acres of arable land with the average wheat yield per acre, and dividing by the amount of wheat needed to support one person per year. It turns out that carrying capacity is primarily driven by the evolution of wheat yields (the circles in Figure 2). Now that we have the curve for carrying capacity (shown with a broken line in Figure 2), it is a simple matter to express the observed population numbers in terms of proportion of carrying capacity "occupied" (Figure 3, dotted line). The detrended – or *relative* – population exhibits two oscillations with peaks around 1300 and 1640. According to the standard methods of time-series analysis, the perioidicity in this data is statistically significant.

The next step is to examine the potential interactions between the population oscillations and some other socio-economic variables. The obvious place to start is the data on wages, since one of the venerable theories for demographic cycles, advanced by T. R. Malthus (1798) proposes that increased population leads to lower wages, and lower wages, in turn, cause population to decrease. Data on real wages (that is, nominal wages deflated by the cost of a standard bundle of consumables) in England was published by Allen (Allen 2001). Plotting these data together with population (Figure 3) we see that both variables oscillate with the same period, but completely out of phase – that is, when population reaches a peak, real wage hits a trough, and vice versa. Plotting the data in a phase-plot (a graph in which each variable is plotted along its own axes) we see that the trajectory moves back and forth along the same, essentially one-dimensional path (Figure 4). But as explained in Turchin (2003b), such a pattern in the phase-plot is inconsistent with the hypothesis that the dynamical interaction between the two variables is what drives the cycle. In a cycle, the two interacting variables are always phase-shifted with respect to each other by approximately one-quarter of the period. In a phase plot this phase shift generates a circular trajectory. Thus, we conclude that there must be another variable, which we have not yet identified, that drives the population cycle. It is clear that changes in population and in real wage are related (in fact, it is uncanny how closely real wage dynamics mirror population curve). But the nature of the relationship is not such that would produce a long-term cycle that we observe.

What other variables can we examine? We know that the mid-fourteenth century population collapse in England was associated with an epidemic of bubonic plague – the Black Death. Additionally, the population decline in the late-seventeenth century was also associated with plague (for example, the great plague of London). We can use the data on plague prevalence published by Biraben (1975). Biraben's data provide us with an index of plague intensity – the number of locations reporting plague outbreaks. We plot Biraben's data (solid curve) together with population data (dotted curve) in Figure 5a (the curves stop at the end of the seventeenth century, because the bubonic plague went extinct in England at that time). We observe a complete parallelism between the movements of the two curves. When plotted in the phase space, the trajectory again traces out a one-dimensional path (Figure 5b). Using the same logic as in the case of the real wage, we must again reject the hypothesis that population cycles are driven by the population interacting with epidemic – the phase relations are all wrong.

A third variable that we can examine is the frequency of internal warfare. This index was constructed by merging together the lists of revolutions, civil wars, and major rebellions constructed by Tilly (1993) and Sorokin (1937) (excluding such events in Ireland, where they reflect colonial activity of the English empire, rather than socio-political dynamics internal to England proper). The resulting index assigns "1" to years with civil war and "0" to years without civil wars (the vertical spikes in Figure 6a). In order to use this variable in the time-series analysis we must smooth it, the smoothed curve is shown as a solid curve.

Plotting population and socio-political instability in the phase plot we observe a pattern that is qualitatively different from those obtaining in the case of real wage and epidemic. Now we see that the trajectory traces out a circle in the phase space (Figure 6b). This pattern is consistent with the hypothesis that it is the dynamical interaction between population and instability that drives the observed secular cycle. On the other hand, this analytical result cannot be taken as a proof of the hypothesis, because we have not exhaustively examined all possible social variables that in principle could provide an explanation for the oscillations (which is in principle impossible).

In summary, this example illustrates how we can capitalize on the phase relationships between various dynamical variables in order to test hypotheses about mechanisms that underlie the observed cycles. Thus, we found that population and disease prevalence oscillated completely in synchrony, which leads us to reject the disease as the factor responsible for oscillations. In fact, disease apparently plays a role of reducing the amplitude of oscillations: it is highest when population is at the peak (and therefore helps to prevent further population growth) and lowest when population is in the trough (facilitating population increase). By contrast, sociopolitical instability is highest when population is already declining, and therefore it acts to accelerate the decline and increase the amplitude of the cycle. Real wages, however, are completely out-of-phase with respect to population dynamics. It may seem strange that it acts in the same way as epidemics, but this point can be better seen by looking at an inverse real wage, or an index of "misery" (Figure 7). Here we see that the index of misery acts precisely as the plague. Thus, misery (and, by implication, real wage) is a factor that, like the epidemic, tends to reduce the amplitude of oscillations (when population is high, misery is also high, and prevents further population increase due to its effect on increased mortality and reduced birth rate). There is definitely a connection between population change and economic misery, in that Malthus was correct. But the interaction between population and misery does not cause cycles, we can reject that particular aspect of Malthusian theory.

Conclusions

From this analysis we concluded that real wages and disease act as first-order factors in driving cycles which respond without a lag. However, these factors are incapable of driving the observed oscillations. Rather, we observe that sociopolitical instability acts as a second-order factor that is phase-shifted with respect to population density and which can potentially drive the cycle.

Our theory, following Goldstone (1991:25) is that population growth in excess of the productivity gains of the land leads to state fiscal crisis because of persistent price inflation. This in turn leads to expansion of armies and rising real costs. Population growth also leads to an increased number of aspirants for elite positions which puts further fiscal strains on the state leading to increased intra-elite competition, rivalry and factionalism.

These strains on the state lead to popular discontent due to falling real wages, rural misery, and urban migration. Intensification of these trends eventually causes state bankruptcy and consequent loss of the military control and elite movements of regional and national rebellion. A combination of elite-mobilized and popular uprisings manifest the breakdown of central authority. This sociopolitical instability affects population growth (Turchin 2003b) through higher mortality due to increases in banditry, internal war, starvation; migration, emigration; spread of disease; and lower birth rates due to uncertainty, life on the move, infanticide. These combine to lower productive capacity through destruction of infrastructure (e.g., irrigation, flood control) and abandonment of exposed lands.

Final Comments:

We now return to the issue of synchrony. We argue, but have not demonstrated, that secular cycles – long-term oscillations in socioeconomic variables – are common to all tributary world-systems and component states of world-systems. In order to explain why some areas experience related, synchronous cycles in population size, population growth or change, city size, and state or empire size we need to discover a mechanism or mechanisms that link them. What we learn from theories developed in natural sciences (and specifically, models of population ecology) is that the linking mechanism[s] need not be of the same period, or even cyclical, nor do they need to be exceptionally strong. Relatively weak links, such as trade in preciosities or prestige and luxury goods, low levels of migration, and spread of disease are sufficient to bring about synchrony. Certainly, too, climate shifts, especially those that are "global" in the population ecology sense – "system-wide" – could also bring about synchrony.

Future research needs to focus on these mechanisms. The linkage between east and west Asia, but not with south Asia suggest that the mechanism is either **not** global climate change, or that somehow the relevant climatic shifts only occurred north of the Himalayan chain. An alternative might be a parallel linkage between South and Southeast Asia that was sufficiently strong to bring those areas into synchrony and block synchrony with the regions of northern Eurasia. Whatever the results of future research on these issues, we will understand more deeply how various structural dynamics shape and limit processes of social and ecological change. Here again the linkage of cultures in precontact southwest and southeast North America (Neitzel 1999) is suggestive, but far from definitive, that synchronous linkage has long been a significant factor in social evolution, and has played an important role in shaping human – environmental interactive dynamics.

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Figure 1– Dimensional Continua of Mechanisms of Spatial Synchronicity

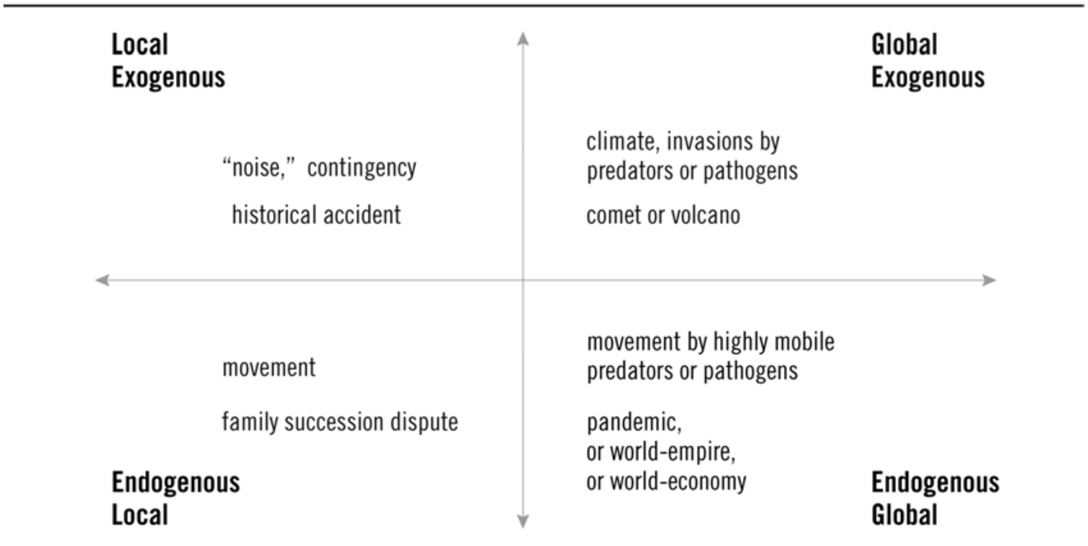


Figure 1

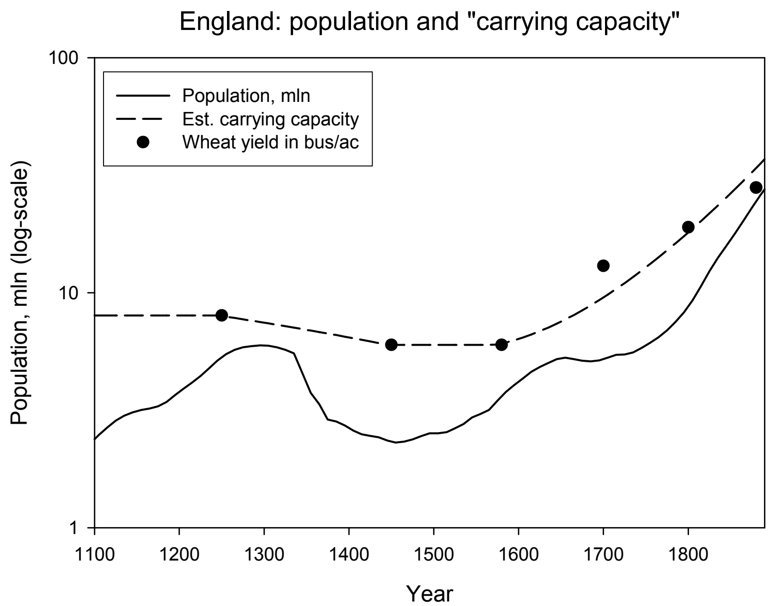


Figure 2

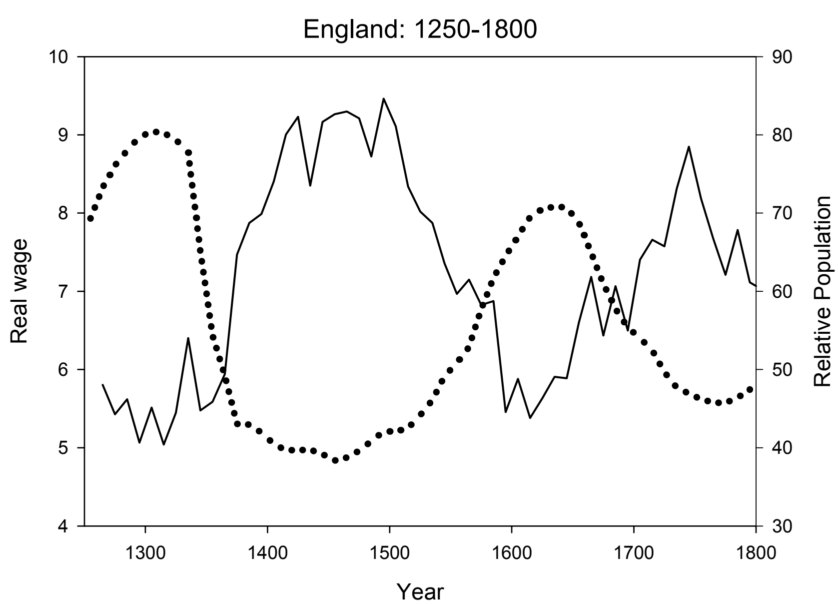


Figure 3

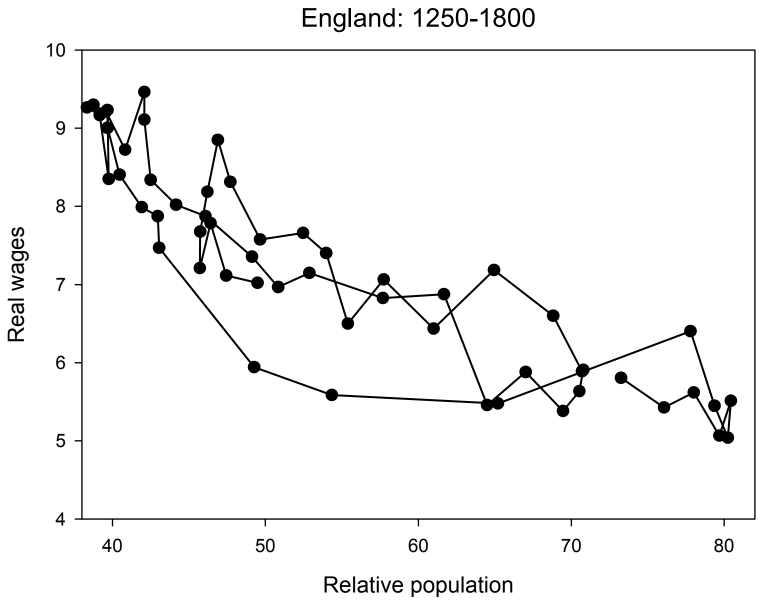

England: 1250-1800
Real wages
Relative population
10
9
8
7
6
5
4
40
50
60
70
80

Figure 5

(a)


England: 1350 - 1700
Population (detrended)
Plague incidence (log scale)
70
60
50
40
30
100
10
1300
1400
1500
1600
1700

(b)

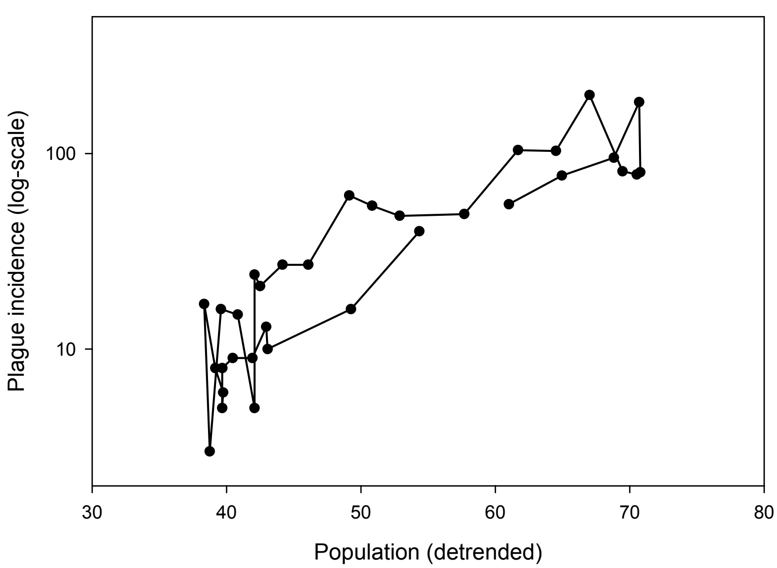
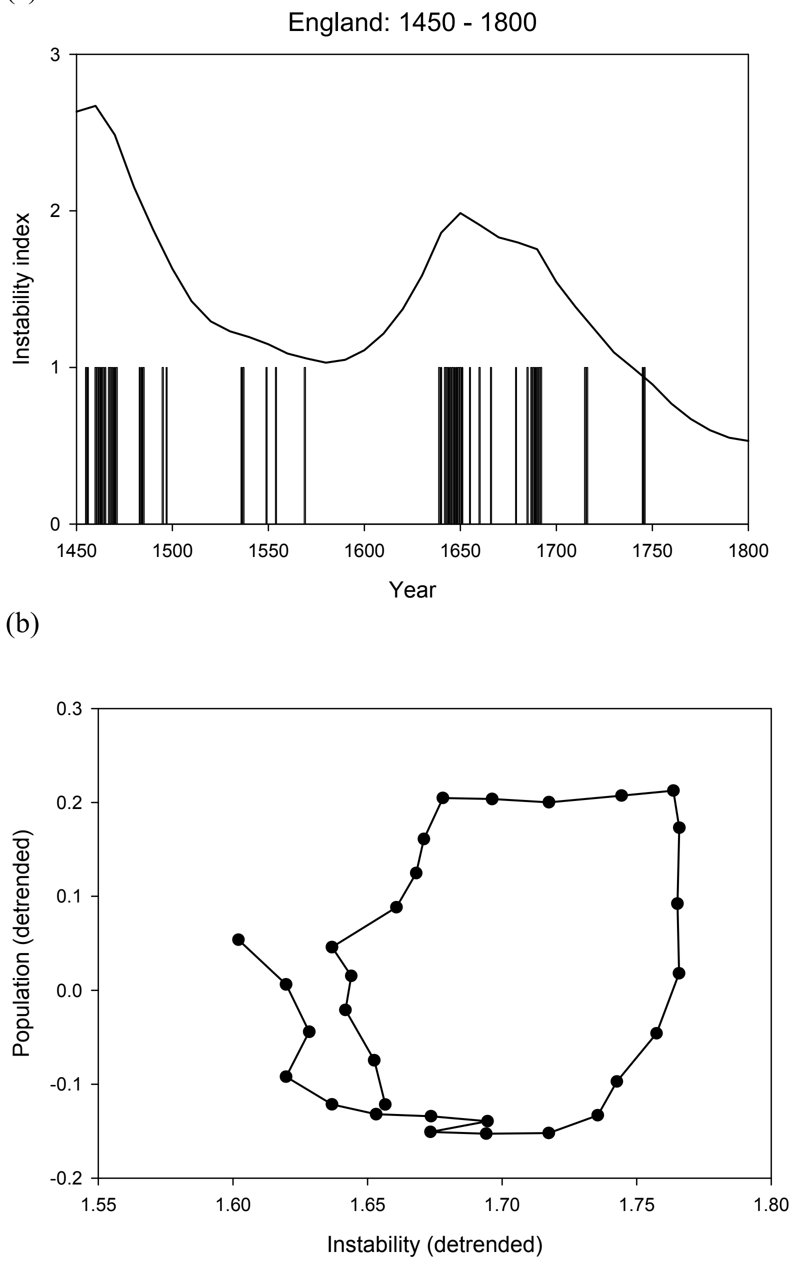

Plague incidence (log-scale)
100
10
30
40
50
60
70
80
Population (detrended)

Figure 5

(a)


England: 1450 - 1800
Instability index
Year
0
1
2
3
1450
1500
1550
1600
1650
1700
1750
1800
Population (detrended)
Instability (detrended)
0.3
0.2
0.1
0.0
-0.1
-0.2
1.55
1.60
1.65
1.70
1.75
1.80

(b)

Figure 6


England: 1250 - 1800
Inv. wage
Rel. Pop
Variables, log-scale, arbitrary const.
1200
1300
1400
1500
1600
1700
1800
Year

Figure 7