THE WORLD SYSTEM AND THE EARTH SYSTEM

GLOBAL SOCIOENVIRONMENTAL
CHANGE AND SUSTAINABILITY
SINCE THE NEOLITHIC

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World-Systems in the Biogeosphere: Urbanization, State Formation and Climate Change Since the Iron Age

CHRISTOPHER CHASE-DUNN, THOMAS D. HALL,
AND PETER TURCHIN

In Kurt Vonnegut's *The Sirens of Titan* a traveler from another solar system has crash-landed on one of the moons of Jupiter and is using his last bit of fuel to beam forces onto the Earth in order to send a message home. His efforts induce the Central Asian steppe nomads to behave in a way that causes successive Chinese states to build the Great Wall in the form of a script that appears from space as a rescue plea. This trope of distant forces affecting human history is an ironic tool in the hand of the fiction-smith who pokes fun at us for our hapless intentions. World-historians have hypothesized other powerful mechanisms by which macro-social processes may have been shaped by exogenous forces.

Since Ellsworth Huntington's *Climate and Civilization* there has been a growing literature on how spatial and temporal variations in rainfall, temperature, prevailing winds, and episodic weather extremes have influenced the course of history. Archeologists routinely invoke climate change as the explanation for social and cultural developments. As much more has been learned about the patterns of global weather these accounts have become more sophisticated. Brian Fagan's (1999) *Floods, Famines and Emperors: El Niño and the Fate of Civilizations* is a recent and compelling version. But instead of painting the humans as inert victims of powerful forces, Fagan argues that climate change has acted as the critical spur that pushed people to invent and implement radical new ways of interacting with nature and with one another.

Mike Davis's (2001) *Late Victorian Holocausts: El Niño Famines and the Making of the Third World* depicts how droughts caused by El Niños in the nineteenth century interacted with the rapid integration of peripheral regions

into global markets in a context of colonialism and neocolonialism to bring about unprecedented huge famines and epidemic disease fatalities in Brazil, India, China, and the Philippines.

There is also an important literature about how human action may affect the climate. Much of this is focused on anthropogenic global warming in the twentieth century, but there is also a literature on how deforestation, irrigation, and other land-use patterns may have affected local weather in the past (for example, Chew 2001). A growing research tradition on urban ecology has discovered the phenomenon of the "urban heat island," an example of anthropogenic effects on the local weather (Gallo & Ower n.d.).

Here we present a theoretical and empirical framework for the study of human societies and their interactions with the biogeosphere on a millennial time scale. We begin by noting that the world-systems approach focuses on human interaction networks, which enables us to examine systemic combinations of very different kinds of societies. This makes it possible to study multicultural systems and core-periphery relations as cases that can display dynamics of social evolution. All world-systems display oscillations of expansion and contraction, or pulsations. These waves of expansion, now called globalization, have, in the last two centuries, created a single, integrated intercontinental political economy in which all national societies are strongly linked. This chapter investigates the pulsations of regional interaction networks (world-systems) in Afroeurasia over the past 3,000 years. The purpose is to examine the causes of a remarkable synchrony that emerged between East Asia and the distant West Asian/Mediterranean region but did not involve the intermediate South Asian region. The hypothesized causes of this synchrony are climate change, epidemics, trade cycles, and the incursions of Central Asian steppe nomads. This chapter formulates a strategy of data acquisition, system modeling, and hypothesis testing that can allow us to discover which of these causes were the most important in producing synchrony as the Afroeurasian world-system came into being.

One limitation of regional analyses has been the tendency to define regions in terms of homogeneous attributes, either natural or social. A major problem with both the civilizationist and cultural-area approaches is the assumption that homogeneity is a good approach for bounding evolving social systems. Even sophisticated approaches that examine distributions of spatial characteristics statistically must make quite arbitrary choices in order to specify regional boundaries on this basis (for example, Burton et al. 1996). We argue that heterogeneity rather than homogeneity has long been a pervasive aspect of human social systems. The effort to bound systems as homogeneous regions obscures this important fact. Spatial distributions of homogeneous characteristics do not bound separate social systems. Indeed, social heterogeneity is often produced by interaction.

The relationship between natural regions and human interaction networks has been important in cultural ecology, which stresses the ways in which local ecological factors condition sociocultural institutions. While useful for understanding small-scale systems, it is much less compelling in large world-systems because of the scale of interaction networks and the development of technologies that allow imposition of external logics on local ecologies. Some social evolutionists have argued that this means that social institutions have become progressively less ecologically determined (for example, Lenski, Nolan, & Lenski 1995). Rather, we argue that what has happened is that ecological constraints have now become global (Chase-Dunn & Hall 1998).

Spatially Bounding World-Systems

The world-systems perspective emerged as a theoretical approach for modeling and interpreting the expansion and transformation of the European system as it engulfed the globe over the past five hundred years (Wallerstein 2004). Chase-Dunn and Hall (1997, 2000, 2002) have modified the basic world-systems concepts to make them useful for a comparative study of very different kinds of social systems. Their scope of comparison includes very small intergroup networks composed of sedentary foragers (for instance, Burch 2005; Chase-Dunn & Mann 1998) as well as larger regional systems containing chiefdoms, early states, agrarian empires, and the contemporary global political economy.

The comparative world-systems perspective is designed to be general enough to allow comparisons among quite different systems. Chase-Dunn and Hall (1997) argue that different kinds of interactions often have distinct spatial characteristics and degrees of importance in different sorts of systems. They hold that the question of the degree of systemic interaction between two locales precedes the question of core-periphery relations, and that it is fundamentally an empirical issue rather than an assumption.

Spatially bounding world-systems necessarily must proceed from a locale-centric rather than a whole-system focus. This is because all human societies, even nomadic hunter-gatherers, interact importantly with neighboring societies. However, interaction networks, while always intersocietal, have not always been global. When transportation and communications occurred only over short distances, the world-systems that affected people were small.

Thus, Chase-Dunn and Hall use the notion of "fall-off" of effects over space to bound the networks of interaction that importantly impinge on any focal locale. The world-system of which any locality is a part includes those peoples whose actions in production, communication, warfare, alliance, and trade have a large and interactive impact on that locality. It is also important to distinguish between endogenous systemic interaction processes and exogenous impacts that may importantly change a system but are not part of that system. The fact that maize diffused from Mesoamerica to eastern North America need not mean that the two areas were part of the same world-system. Similarly, virgin soil epidemics are not necessarily evidence of a system. Interactions must be two-way and regularized to be socially systemic.

Chase-Dunn and Hall (1997) identify several different kinds of networks with different spatial scales:

1. Information Networks (INs)
2. Prestige Goods Networks (PGNs)
3. Political/Military Networks (PMNs)
4. Bulk Goods Networks (BGNs)

The largest networks are those in which information travels. Information is light and travels a long way, even in systems based on down-the-line interaction. These are termed Information Networks (INs). A usually somewhat smaller interaction network is based on the exchange of prestige goods or luxuries that have a high value/weight ratio. These are called Prestige Goods Networks (PGNs). The next interaction network comprises polities that are in alliance or at war with one another. These are called Political/Military Networks (PMNs). The smallest networks are those based on a division of labor in the production of basic everyday necessities such as food and raw materials. These are Bulk Goods Networks (BGNs). Figure 1 illustrates how these interaction networks are spatially related in many world-systems.

The spatial characteristics of these networks clearly depend on many things: the costs of transportation and communications, and whether interaction is only with neighbors or whether regularized long-distance trips are being made. These factors affect all kinds of interaction; thus the relative size of networks is expected to approximate the sequence shown in Figure 1. As an educated guess, for instance, we would suppose that fall-off in the PMN generally occurs after two or three indirect links.

Chase-Dunn and Hall (1997) distinguish between two types of core-periphery relations: core-periphery differentiation and core-periphery hierarchy. Core-periphery differentiation exists when two societies are in systemic interaction with each other and one of these has higher population density and/or greater complexity than the other. Core-periphery hierarchy exists when one society dominates or exploits another. These two types of relations

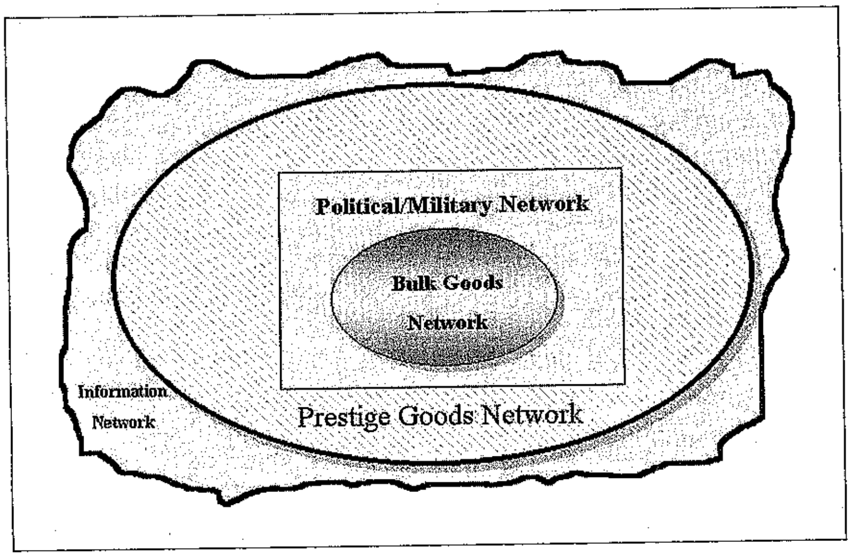

Figure 1 • Nested interaction networks.

often go together, but there are important instances of reversal (for example, the less dense, less complex Central Asian steppe nomads who exploited agrarian China [see Barfield 1989; Kradin 2002]). Hence this distinction is both theoretical and empirical. The question of core-periphery relations needs to be asked at each level of interaction designated above. It is more difficult to project power over long distances, and thus one would not expect to find strong core-periphery hierarchies at the level of Information or Prestige Goods Networks. Figure 2 illustrates a core-periphery hierarchy.

Core-periphery hierarchies are important in processes of social evolution because semiperipheral societies, those that are intermediate between core regions and peripheral hinterlands, are fertile locations for institutional innovations and frequently are the key actors that transform the developmental logic of world-systems, called "semiperipheral development" (Chase-Dunn & Hall 1997, Chapter 5). Semiperipheral marcher chiefdoms have conquered more senior core chiefdoms to form larger and more centralized complex chiefdoms, as have the better-known semiperipheral marcher states (for instance, Chin China, Assyria, Rome, and Islamic Arabia). Semiperipheral capitalist city-states (the Phoenicians, the Italian city-states, the Hanseatic cities, Malakka) were agents of commercialization in the interstices of tributary empires. In the modern world-

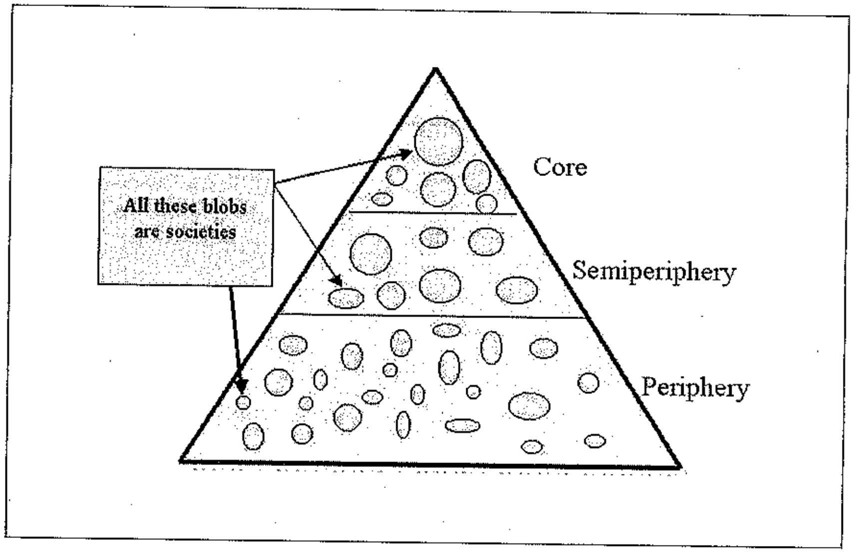

Figure 2 • Core-periphery hierarchy.

system, it was the semiperipheral and capitalist Dutch republic, then England, and then the United States that rose to hegemony and further globalized the world economy. Semiperipheral development is still an important pattern in the twentieth and twenty-first centuries (Chase-Dunn & Boswell 2002).

Recently Turchin (2003b:62) has pointed out that not all semiperipheries are "hotbeds" of marcher state development. Focusing specifically on the territorial dynamics of states, he has shown that large agrarian states ("empires") almost always originate in areas where frontiers of previously existing empires coincide with intense ethnic or cultural ("civilizational") fault lines. Two typical situations can be distinguished. One is a frontier between a large empire and a stateless (but not necessarily chiefdomless) hinterland. Such tribal war zones abutting imperial frontiers are notorious for their ability to produce aggressive expansionist states (examples: the Roman Empire and the Germans, the succession of Chinese empires and steppe nomads). The second situation is a frontier zone between two empires dominated by different exclusionary religions. For example, a number of European empires originated from the frontier between Islam and Christianity in Europe and Asia Minor (Castile-Spain, Austro-Hungary, Muscovy-Russia, and the Ottoman empires).

World-System Cycles: Rise-and-Fall and Pulsations

Comparative research reveals that all world-systems exhibit cyclical processes: the rise and fall of large polities and pulsations in the spatial extent and intensity of trade networks. Rise and fall corresponds to changes in the centralization of political-military power in a set of polities—an "international" system. It is a question of the relative size and distribution of power across a set of interacting polities.

All world-systems in which there are hierarchical polities experience a cycle in which relatively larger polities grow in power and size and then decline. This applies to interchiefdom systems as well as interstate systems, to systems composed of empires, and to the modern rise and fall of hegemonic core powers (for example, Britain and the United States). Although very egalitarian and small-scale systems such as the sedentary foragers of northern California (Burch 2005; Chase-Dunn & Mann 1998) do not display a cycle of rise and fall, they do experience pulsations.

All systems, including very small and egalitarian ones, exhibit cyclical expansions and contractions in the spatial extent and intensity of exchange networks. Different kinds of trade (bulk versus prestige goods) usually have different spatial characteristics and may exhibit different temporal sequences of expansion and contraction. Again, this is an empirical issue. In the modern global system large trade networks cannot get spatially larger, because they are already global in extent, but they can get denser and more intense relative to smaller networks of exchange. Much of what has been called globalization is simply the intensification of larger interaction networks relative to the intensity of smaller ones. Research on trade and investment shows that there have been two recent waves of integration: one in the last half of the nineteenth century and the most recent since World War II (Chase-Dunn, Kawano, & Brewer 2000). Whether rise-and-fall and pulsations are correlated in different types of world-systems is also an empirical issue.

Chase-Dunn and Hall (1997) have contended that the causes of rise and fall differ depending on the predominant mode of accumulation. One big difference between the rise and fall of empires and the rise and fall of modern hegemons is in the degree of centralization achieved within the core. Tributary systems alternate back and forth between a structure of multiple and competing core states, on the one hand, and core-wide (or nearly core-wide) empires, on the other. The modern interstate system experiences the rise and fall of hegemons, but these never take over the other core states to form a core-wide empire. This is the case because modern hegemons are pursuing a capitalist, rather than a tributary, form of accumulation.

Analogously, rise and fall works somewhat differently in interchiefdom systems because the institutions that facilitate the extraction of resources from distant groups are less fully developed in chiefdom systems. David G. Anderson (1994) has examined the rise and fall of Mississippian chiefdoms in the Savannah River valley. This cyclical process begins with a chiefly polity extending control over adjacent chiefdoms and establishing a two-tiered hierarchy of administration. At a later point, these regionally centralized chiefly polities disintegrate back toward a system of smaller and less hierarchical polities.

Chiefs have relied more on hierarchical control of kinship relations, ritual, and imports of prestige goods than have the rulers of true states. These chiefly techniques of power are all highly dependent on normative integration and ideological consensus. States developed specialized organizations for extracting resources that chiefdoms lacked: standing armies and bureaucracies. States and empires in tributary world-systems were more dependent on the projection of armed force over great distances than modern hegemonic core states have been. The development of commodity production and mechanisms of financial control, as well as further development of bureaucratic administrative techniques, has allowed modern hegemons to extract resources from faraway places with much less overhead cost.

The development of new techniques of exerting power has made core-periphery relations ever more important for competition among core powers and has altered the way in which the rise-and-fall process works in other respects. Chase-Dunn and Hall (1997:Chapter 6; see also 2000, 2002) have argued that population growth in interaction with the environment and changes in productive technology and social structure produce social transformations that are marked by cycles and periodic jumps. This is because the parameters of each world-system oscillate owing both to internal instabilities and environmental fluctuations. Occasionally, on an economic upswing, people solve systemic problems in a new way that allows for substantial expansion. We want to explain such expansions, evolutionary changes, and collapses in terms of systemic logic. That is the point of comparing world-systems.

The multi-scalar regional method of bounding world-systems as nested interaction networks outlined above is complementary to a multi-scalar temporal analysis of the kind suggested by Fernand Braudel. Temporal depth, the *longue durée*, needs to be combined with analyses of short-run and middle-run processes to allow us to fully understand social change. A key example of this is Jared Diamond's (1997) study of the original distribution of zoological and botanical resources. The geographical distribution of those species that could be easily and profitably domesticated explains a significant part of the variation regarding which world-systems were able to expand and incorporate

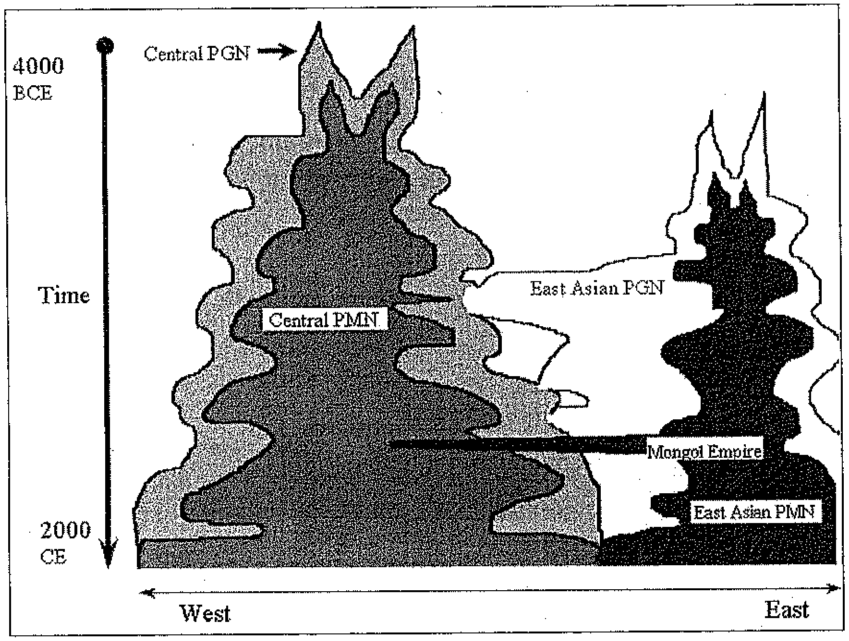

Figure 3 • East-West pulsations and merger.

other world-systems over the millennia. Diamond contends that the diffusion of domesticated plant and animal species occurs more quickly in the latitudinal dimension (East-West) than in the longitudinal dimension (North-South). Thus, domesticated species spread quickly to Europe and East Asia from West Asia, whereas North-South diffusion in both Africa and the Americas was much slower.

The diagram in Figure 3 depicts the process of integration of the East Asian and the West Asian-Mediterranean systems. Both the PGNs and the PMNs are shown, as are the pulsations and rise-and-fall sequences. The PGNs were intermittently linked and then more permanently joined. The Mongol conquerors linked the PMNs briefly in the thirteenth century, but the Eastern and Western PMNs were not permanently joined until the Europeans and Americans established Asian treaty ports in the nineteenth century.

Synchronization of Empires, Cities, and Demographic Waves

Earlier studies have used data on the sizes of both cities and empires to examine different regional interaction systems and the hypothesis that regions distant

from one another were experiencing synchronous cycles of growth and decline (for example, Chase-Dunn & Manning 2002; Chase-Dunn, Manning, & Hall 2000). Frederick Teggart's (1939) path-breaking world-historical study of temporal correlations between events on the edges of the Roman and Han Empires argued the thesis that incursions by Central Asian steppe nomads were the key to East-West synchrony. An early study of city-size distributions in Afroeurasia (Chase-Dunn & Hall 1997:222–223) found an apparent synchrony between changes in city-size distributions and the growth of largest cities in East Asia and West Asia-North Africa over a period of 2,000 years. That led us to examine data on the territorial sizes of empires for similar synchrony, which we also found (Chase-Dunn, Manning, & Hall 2000). Chase-Dunn and Manning (2002) have reexamined the city-size data using constant regions rather than PMNs to see if the East-West synchronous city growth hypothesis holds when the units that are compared are somewhat different. Their results confirm the existence of East-West city-growth synchrony.

Here we present a new analysis of East-West synchrony that uses overall population estimates compiled by McEvedy and Jones (1978). They note a synchrony between East Asia and the Mediterranean area in periods of regional demographic growth and decline during the late first millennium B.C.E. and during the first millennium C.E. Interestingly, McEvedy and Jones (1978:345–346) reject the idea that climate change may have caused this synchrony in favor of a hypothesis of parallel and connected technological and organizational change.

We have computed the partial correlations, controlling for year to remove the trend, of population levels from 1000 B.C.E. to 1800 C.E. among three regions. We stop at 1800 C.E. because the trend becomes exponential after that and would drown out earlier, middle-range variations. What we want to know is whether or not the middle-term ups and downs—what we have called growth versus decline phases—are synchronous or not. We examine four regions: East Asia, South Asia, West Asia-Mediterranean, and Europe.[1] These are the same constant regions that Chase-Dunn and Manning (2002) used to study the synchrony of city growth versus decline phases.

Table 1 shows the partial correlation coefficients of population change estimates for four Old World regions. These have been de-trended in two ways to allow us to look for synchronous growth-decline oscillations across regions. We eliminate the years after 1800 C.E., when most of the regions were undergoing geometric growth rates, and compute the interregional correlations as a partial correlation, controlling for year, which should remove the long-term trend.[2]

The results in Table 1 are somewhat surprising. There are statistically significant partial correlations among all the regions despite our efforts to remove

Table 1 Interregional partial correlations of population change, controlling for year, 1000 B.C.E.–1800 C.E. (population estimates from McEvedy & Jones 1978)

	West Asia-Mediterranean	East Asia	South Asia	Europe
West Asia-Mediterranean	1	.81 (26)	.60 (26)	.79 (26)
East Asia		1	.88 (26)	.95 (26)
South Asia			1	.92 (26)
Europe				1

the long-term trend. The correlation between East Asia and the West Asian-Mediterranean region is higher than that for cross-regional partial correlations of either city or empire size (.81), but it is not as high as some of the other coefficients in Table 1. Curiously, the correlations between Europe and both East Asia and South Asia are very high (.95, .92). The lowest correlation is between West Asia and South Asia (.60), and the correlation between Europe and the West Asia-Mediterranean region is also relatively low, considering that these two "regions" overlap geographically.

It is possible that these high correlations are partly due to the rather coarse temporal resolution of the population estimates that we have extracted from graphs produced by McEvedy and Jones (1978). Our data set is organized in one-hundred-year intervals, a temporal resolution that smooths out most of the growth/decline fluctuations that we are trying to study. Unfortunately, McEvedy and Jones do not present enough detail about the evidence they used to produce their graphs. Figure 4 presents the demographic data in graphical form for the same four regions.

Examination of Figure 4 shows both the long-term trends and the shorter-term variations, though these have been smoothed by the low temporal resolution just discussed. What we see is a long hump that starts slowly in 1000 B.C.E. and winds back down to a low point around 600 C.E. in all the regions except South Asia. In South Asia the slump does not appear. This is the East-West synchrony noted by McEvedy and Jones. After about 600 C.E., all the regions go up again, but then the patterns partly diverge. The East Asian rise is early and steeper. All the regions except South Asia display a partly synchronous decline after the twelfth century. East Asia has another decline in the seventeenth century, and this is also a period of slow growth in Europe and decline in West Asia, but South Asia continues to grow. The West Asian-Mediterranean region does not partake in the rapid population growth that sweeps the other regions after the fifteenth century.

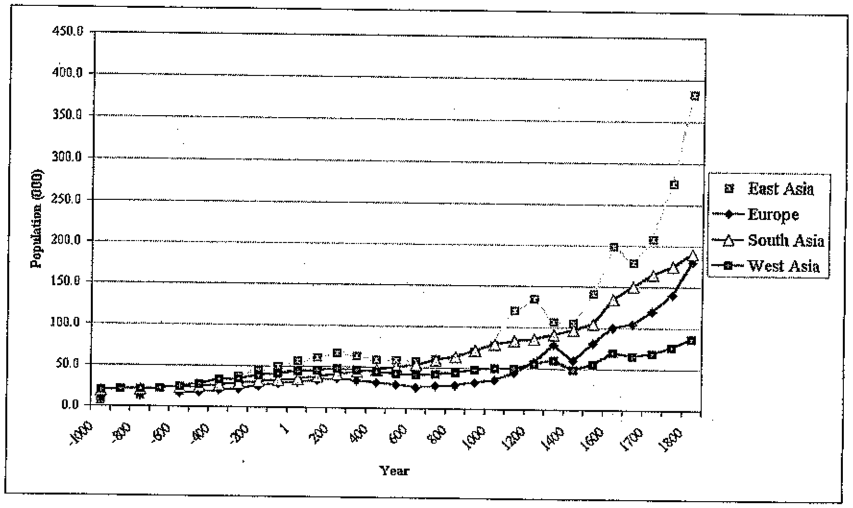

Figure 4 • Regional population growth (McEvedy & Jones 1978).

A rather similar result is obtained by a different approach to the data presented by McEvedy and Jones. First we plot everything on the log-scale, which makes the patterns much easier to see. The log-plot (Figure 5a) makes it clear that the South Asian "data" are mostly extrapolation, being very close to a straight line on a log-scale. Of course, all McEvedy and Jones's data are to a certain degree extrapolation, but it looks like the South Asian data are the most conspicuous case.

We do not want to simply correlate the population numbers between different regions directly, because they are all affected by the same long-term, evolutionary trend. Rather, we have chosen to difference each series, that is calculate $\Delta Y - Y(t+1) - Y(t)$, where $Y(t)$ is log-transformed population number at time t. This is a particularly appropriate procedure in this case, because it yields something known as the *realized per capita rate of change*, the standard quantity that population ecologists calculate. Plotting these differenced log-transformed numbers (rates of change) produces Figure 5b. Cross-correlation coefficients among different regions are given in Table 2.

The results confirm the initial impression that South Asia tends to fluctuate on its own (with all the caveats about these data), whereas the rest are cross-correlated with one another. An additional observation is that the highest correlations are between West Asia and Europe or East Asia, respectively, which makes sense, given the central location of West Asia. Of all regions, West Asia is also the most correlated with South Asia (although the correlation is not quite statistically significant).

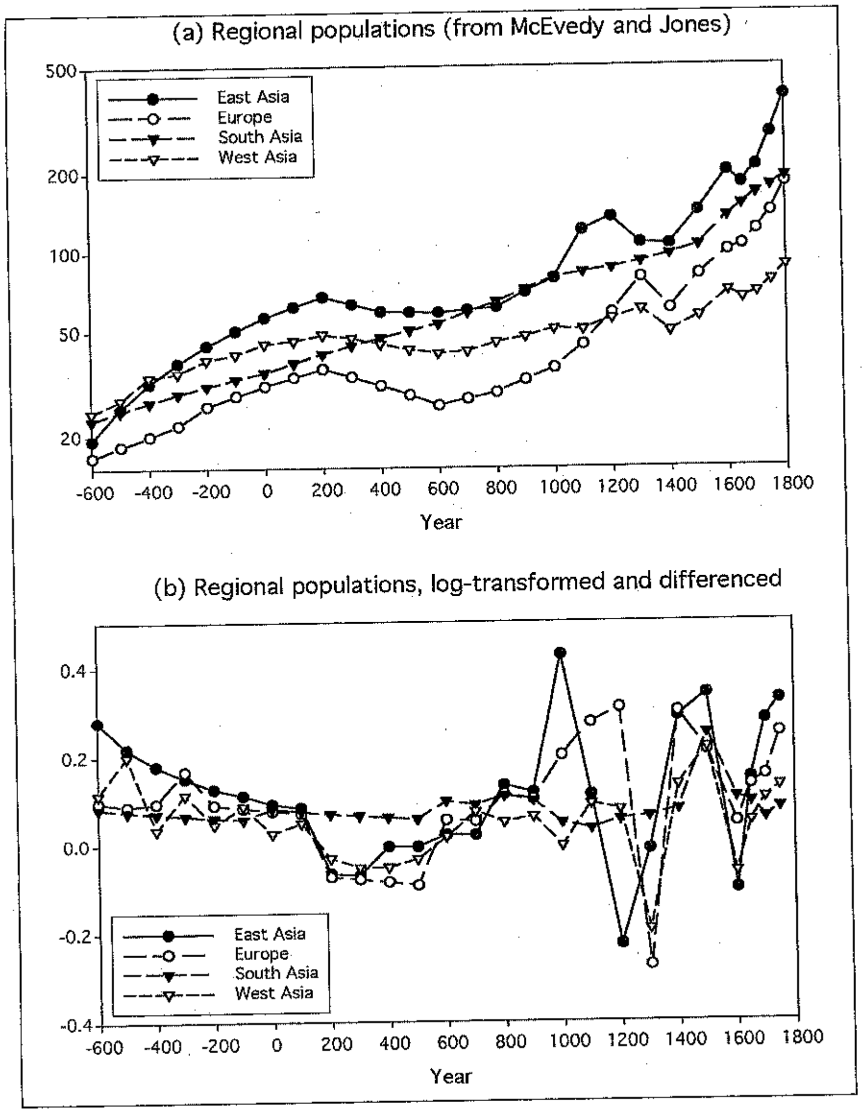

Figure 5 • (a-b) Plots of logged populations and first differences of logs (McEvedy & Jones 1978).

Table 2 Correlations among logged and differenced population scores (boldface italic indicates those significant at the $P < 0.05$ level)

	East Asia	Europe	South Asia	West Asia
East Asia	1	***0.465***	0.247	***0.570***
Europe	***0.465***	1	0.139	***0.767***
South Asia	0.247	0.139	1	0.372
West Asia	***0.570***	***0.767***	0.372	1

The "Moran Effect" in Population Ecology

The cyclical aspects of climate change lead easily to hypotheses about how these may cause certain cyclical (or at least sequential) phenomena in human affairs. This is especially the case when cycles from distant regions appear to be synchronized. Population ecologists model population dynamics of species within adjacent and distant "patches" to explain how predator-prey relationships, food availability, and migration affect the cycles of population growth and decline. P.A.P. Moran's (1953) study of the population cycles of the Canadian lynx led him to formulate what has become known as the "Moran effect"—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 (see Chapter 5 and Turchin & Hall 2003 for a more detailed account). Population ecologists usually have climate change in mind as the most likely source of exogenous shocks.

The important implications of the Moran effect for our problem of the causes of synchrony are that any exogenous shock can bring oscillating systems into synchrony even if the temporal features of the exogenous variable are completely different from the temporality of the local oscillating systems. A meteor impact could reset local systems and put them into synchrony. Turchin and Hall (2003) point out that the best situation for the empirical study of synchrony requires exact measurement and fine temporal resolution, and also many oscillations and many different cases of oscillating systems in order to disentangle different plausible causes of synchrony. These are daunting requisites for our single case of East-West synchrony. We argue, however, that sufficiently accurate and temporally fine data can be feasibly assembled to make it possible to sort out the major causes of East-West synchrony.

Comparable other instances of distant systems that come into weak contact with one another can be found. Within the Old World, the Mesopotamian and Egyptian core regions were interacting with one another by means of prestige goods exchange from about 3000 B.C.E. until their PMNs merged in 1500 B.C.E. Chase-Dunn and Hall (2001) have already examined this case for synchronicity, but have not found it, although the data on Bronze Age city and empire sizes are crude with regard to temporality and accuracy.

The Moran effect implies that synchrony occurs easily because a single exogenous impact that resets systems with similar endogenous oscillations will bring them into synchrony. But if this is true we would expect to find more synchrony than we have found up to now. Population ecology also usually finds greater synchrony in patches that are close to one another than in those that are more distant, but this is not what we find in Afroeurasia. The South Asian system, intermediate between East and West, seems to be marching to its own drummer.

Modeling Climate Change Effects on Population

Patrick Galloway (1986) models the way in which climate change can affect human population growth. He argues that it was climate change that caused the synchrony of demographic cycles noted by McEvedy and Jones (1978). Galloway's model is depicted in Figure 6.

Galloway's model is entirely plausible and could easily be amended to include effects on city growth and empire-formation. But for this model to account for synchrony across regions the changes in temperature (and other climatological variables) would need to also be synchronous, or else there would have to at least be an initial strong climatological shift that affected all the regions during the same period. The only way to sort this out is to obtain indicators of climate change in or near the regions we are studying in the relevant time periods. Knowledge about the climate change record in Greenland will not settle the question, because despite global connections, climate change is ultimately local. Our effort to gather the relevant climate change data has only just begun.

There are a few other questions regarding this model that need to be attended to. On the one hand, where agriculture is marginal and the frost-free season approximates the growing season, such as in many mountainous areas, slight cooling would make agriculture impossible, at least until crops with shorter growing season are introduced. On the other hand, slight warming would make more land available and existing land more productive. This would enhance food production and increase populations. Where conditions are volatile—again not unusual in mountainous areas or desert fringes—there could be considerable fluctuation. As Turchin (2003a) argues, such conditions themselves created strong pressures for change and experimentation. In other

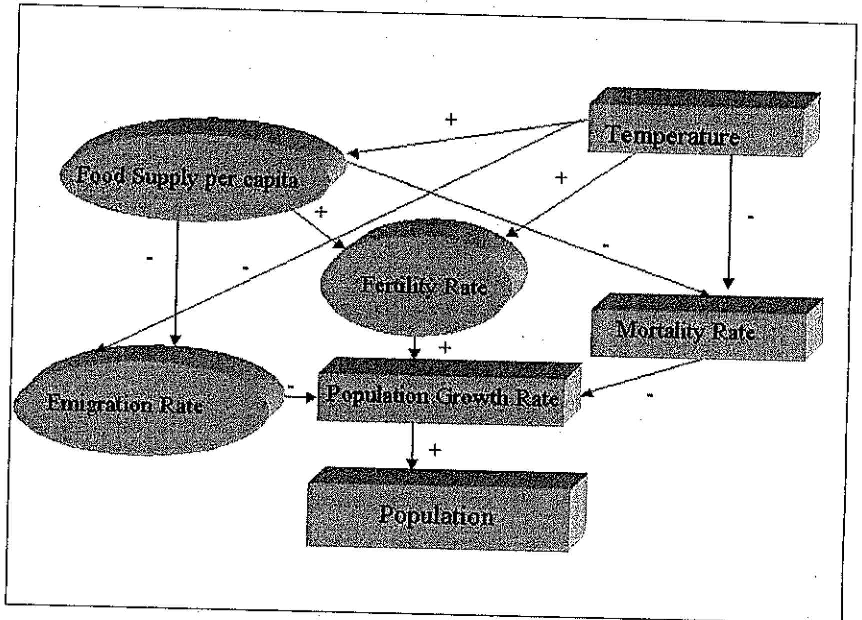

Figure 6 • Galloway's (1986) climate and population model.

areas, such as much of Africa, West Asia, and South Asia, slight increases in temperature would have the opposite effect. A rise in average temperature would make agriculture impossible, whereas a slight cooling would make more land available and available land more reliable. Thus, the effects of climate change depend on what kind of change and on preexisting marginal conditions.

This conclusion suggests another set of reasons why marginal areas that are frontiers or boundaries between biome regimes are hotbeds of change. Volatile conditions force populations in such areas to be more flexible. Also, such areas often serve as a "coal miner's canary," signaling approaching climate changes already when they are quite small.

A Comprehensive Model of the Causes of Interregional Synchrony

We can now propose a comprehensive model of the plausible causes of East-West synchrony. The purpose of complex causal modeling is to allow us to discover the relative strengths of different causative mechanisms by examining the logical implications of the posited relations and operant parameters. Figure 7 depicts a complex causal model that contains the hypothesized factors resulting in the East-West synchrony discussed above. This model can be translated into a

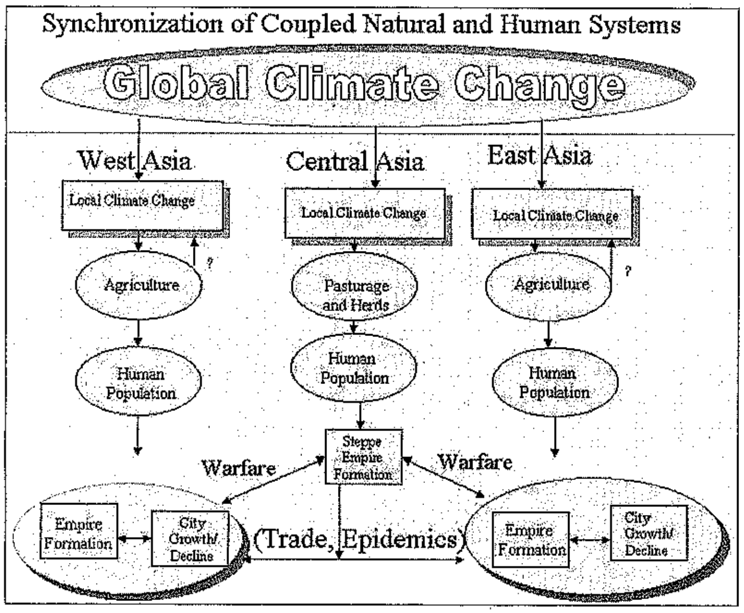

Figure 7 • Comprehensive East-West synchrony model.

complex system of structural equations and estimated parameters that allow us to examine the conditions under which causation can lead to synchrony. In future work, we plan to combine this theoretical exercise with an effort to improve our empirical knowledge of the population sizes of cities, the territorial sizes of empires, and climate change over the past 3,000 years (cf. Pasciuti & Chase-Dunn 2002). By approaching the problem through both induction and deduction we hope to be able to estimate the relative strengths of the different possible causes of East-West synchrony. The outcome should be a better understanding of the way in which human social systems have interacted with biological and geological processes in world history.

Notes

1. The West Asia/Mediterranean region includes the whole Mediterranean littoral so as to encompass the whole interactive city system that originated in West Asia and spread to the Mediterranean with Etruscan, Greek, and Phoenician migration and the emergence of the Latin cities. Thus Europe and the West Asian-Mediterranean region are geographically overlapping.
2. De-trending with a partial correlation for year assumes that the temporal relationship is linear, whereas it may be an accelerating trend. It is possible that this linear de-trending does not remove the entire millennial trend.

CHAPTER 10

Eurasian Transformations: Mobility, Ecological Change, and the Transmission of Social Institutions in the Third Millennium and the Early Second Millennium B.C.E.

KRISTIAN KRISTIANSEN

In this article I explore the origin and nature of the social and economic processes that in later prehistory transformed the Eurasian continent from a large but enclosed marginal region into a highly dynamic and mobile interaction zone connecting eastern and western Asia. The basic components in this process were the adoption of a nucleated family structure suited for expansion, incorporation, and the transmission of mobile wealth, in combination with the formation of an agropastoral economy based on herding, wagons, and mobile property. This led to an ecological transformation that created open steppelike environments from northwestern Europe to east of the Urals. By the end of the second millennium B.C.E. these historical processes had transformed Eurasia into a vast interaction zone for mobile, warlike pastoral nomads, linking eastern and western Asia to a common historical pulse.

Mobility and Ecological Transformation

Today it can be stated with some certainty that the third and early second millennia B.C.E. was a period of major social change over wide areas in Eurasia (Kuzmina 2002; Sherratt 1997), and further that this change was in part linked to a complex pattern of interaction, ranging from travel and small-scale population movements to large-scale migrations. It was based on the formation of a new economy and a concomitant social and religious order with a tremendous capacity for expansion and incorporation. Regional series of C14-dating define the beginning of this major expansion within a very narrow time