Technology development and political and economic power: evolution of global inequality

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Abstract

Global inequality, in combination with various global problems, has been one of the most pressing concerns of today's world. There are numerous models that explain the development of technology, political and economic power concentration, and resulting social inequality within a single society or region. The models that apply global and long-run perspectives having world-systems as a unit of analysis, however, are rare. This study conducts simulation modeling to examine the formation of hierarchies among polities through the expansion of political economic networks and concentration of power having evolving technologies. Two types of technology—subsistence technologies and technologies of power—have evolved for successful economic and political interactions as well as dominations among polities, resulting in the formation of global hierarchy. The dynamics are modeled and simulated by numerically solving partial differential equations and integro-differential equations that describe polity interactions through trade and warfare networks and selection of advantageous technologies. The validity of the model is examined using city population and state/empire size data since 2000BCE to the present. Models with such a broader perspective allow explanation of the fundamental relationship between technological development and political economic power, which will shed light on the issue of global inequality in today's world.

Keywords—world-systems; global inequality; subsistence technology; technology of power

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Extended Abstract

There have been a growing number of studies that model the historical dynamics of human societies applying agent-based models to study social, political, economic, cultural, geographic, and ecological processes. The questions of the evolution of complex societies through the interactions and networks with neighboring societies over time (Gavrilets, Anderson, and Turchin 2010) or the issues about the relationship between archaic societies with environmental dynamics (Kohler, Gumerman, and Reynolds 2005; Kohler, et al 2012) are studied with the application of agent-based simulation modeling. Simulation modeling is utilized to test the theoretical, assumptions of the studies with historical, geographic, or archaeological data to advance scientific understanding of the issue. Most of such simulating social dynamics approaches are, however, focused on specific regional spaces or particular historical time. But much recent simulation study addresses the modeling approach over long-run evolutionary history by having world history as a master unit of analysis (Turchin, Currie, Turner and Gavrilets 2013).

Applying the world-systems perspectives, the current study examines the evolution of concentration of power through political and economic interactions and networks. It further analyzes the role of the development of different types of technologies that are significant for the evolution of power concentration.

The growth and decline of polity size and the power of polities reveal cyclical processes in history—states and empires expand and contract their size through conquests and domination of neighboring polities. Yet, the process is not simply a repetitive cycle of rise and fall. It occasionally involves significant changes in the scale of polity sizes. Empirical analysis of the size of polities shows that there are sporadic, yet dramatic, increases in their sizes, forming upsweeps of growth (Chase-Dunn et al 2010). Climate change or epidemic diseases sometimes play a part in these upsweeps of polity size, but more direct cause is internal technological advancements and organizational innovations through that occur in the context of a polity's interactions with neighboring polities. The innovation of technologies allows sustaining and growing populations within a polity, resolving population pressures on resources. The growing polities also develop new organizational technologies to control and dominate other polities, and these new innovations become institutionalized and diffuse. This is considered as a phase in the socio-cultural evolution of institutions in which significant changes occur in the scale of social activities and the sizes of polities. Technology, in this study, is thus broadly defined. Technological change involves not only the innovation of technologies for subsistence production (i.e., subsistence technology) (Lenski 2005) but also the innovation which allows humans to develop institutions to control and sustain much larger-scale societies (i.e. technologies of power). It is further considered that there have been evolutionary shifts in the ways that polities interact—from intensive warfare basis to trade basis—to dominate and control other polities (Chase-Dunn and Hall 1997).

Based on the theoretical assumption that social cohesion develops culturally heterogeneous frontiers in ethnic boundaries where intense competitions and warfare are likely, studies in population ecology explain warfare as the main mechanism for the formation of large-scale states/empires (Gavrilets, Anderson, and Turchin 2010). In combination with the theory of evolutionary biology which asserts that evolutionary selection favors groups with stronger solidarity, they further argue that competition by means of intense warfare helps to diffuse sociality within polities (Gavrilets, Anderson, and Turchin 2010; Turchin, Currie, Turner and Gavrilets 2013), making the polities develop stronger solidarity, and hence to form larger-scale and more integrated polities.

The model we are developing applies the theoretical framework of multi-level selection to political and economic dynamics. Selection operates favorably on polities that adopt technologies and institutions that are advantageous in the competition among polities that occurs through warfare and trade. The goal of this study is to examine the formation of hierarchies among polities based on the evolutionary selection of different types of technologies (—subsistence technologies and technology of power).

Model Design

The model simulates the evolution of world-systems for the period between 2000BCE and the present. The period is divided into three subperiods: 2000BCE to 1500BCE (mixture of settlement/city and state/empires); 1500 BCE to 1500AD (formation of large-scale empire is predominant), and 1500 to present (development of imperial colonialism and neo-colonialism). The period starts from 2000BCE since this is the time the empirical data become available. The period is divided into three periods to analyze the difference in the relationship between technologies and political and economic power

The modeling area includes the whole region of the earth. A unit of analysis is world-systems which comprises multi-layer polities (i.e., settlement/city and state/empire). It starts from the regional world-systems where settlements interaction occur separate locations through trade and warfare. Trading process includes bulk goods for short distance and prestige goods for long distance trade. The networks are bounded by warfare between polities. They are gradually connected to single world-systems after 1500AD. A set of constant world regions are compared for their characteristics.

The model simulates interactions of polities in a two-dimensional spatial grid. The model is two-layered, and the interacting polities have two categories. One is settlement (city), and the other is polity (state or empire). A state is a larger unit, and one or more settlements are located within a state. Settlement can be independent from state if a settlement has enough political and economic power and autonomy. Polities (settlements and states) interact with other polities and create political and economic network connections, extending their interactions. The size of a settlement is determined by the population size residing in the settlement. Each cell in the grid is considered as 100 kilometers times 100 kilometers in size. The territorial size of settlement is determined by how many settlements get together to form a single polity. The size of a polity is determined by the addition of the number of settlements included within the jurisdiction of the polity. Polity territorial size is thus calculated by summing up the number of settlements in the polity in the model, and it is examined with the empirical data of territorial size of polity.

Polities interact with other polities to increase their wealth and territory. Through warfare, polities dominate or sometimes make allies with other polities. Warfare can decrease or exterminate the populations in settlements or take over the land of polities. Through trade, polities dominate other polities by having tributary relationships or making allies of other polities. The model simulates the growth of territory and connections among settlements and polities through trade and warfare.

World-systems are formed with multiple-level political and economic networks. These networks comprise both local interaction processes among neighboring polities as well as extended political and military networks of polities. In grid cells, each settlement has four neighboring cells which can be empty lands or up to four settlements. Diffusion of technology through warfare and trade of neighboring cells is simulated by numerically solving partial differential equations. The partial differential equation thus assumes local interaction and diffusion of technologies among polities. The diffusion of technology through trade and warfare networks with distant polities is simulated by numerically solving integro-differential equations. A kernel used in the equation determines the distance of polities that regulate the network dynamics. The integro-differential equations thus allow the occurrence of interactions over a variety of scales. Partial differential equations and integro-differential equations are both discretized for reducing computational complexity. Therefore, the time step is discrete, and each time step represents a year.

Simulation of the model is conducted to examine the political and economic power concentrations that occur among polities (i.e., global stratification) in the three periods—from regional-scale settlement interactions to global-scale state and empire networks. The model is verified with historical data of city populations and state/empire territorial sizes since 2000 BCE. The simulation study of the evolutionary time span will help understand and explain the underlying processes of political and economic power dynamics that have resulted in the global inequalities of today's world.

References

Kohler, Timothy, George Gumerman, and Robert Reynolds, 2005. "Simulating Ancient Societies: Computer Modeling is Helping to Unravel the Archaeological Mysteries of the American Southwest." *Scientific American*. pp. 76-83. July.

Kohler, Timothy, R. Kyle Bocinskya, Denton Cockburnc, Stefani Crabtreea, Mark Variend, Kenneth Kolme, Schaun Smithf, Scott Ortman, and Ziad Kobtic. 2012. "Modelling prehispanic Pueblo societies in their ecosystems" *Ecological Modeling* 241: 30-41.

Gavrilets, Sergey, David Anderson, and Peter Turchin. 2010. "Cycling in the Complexity of Early Societies" *Cliodynamics*, 1(1).

Turchin, Peter, Thomas Currie, Edward Turner, and Sergey Gavrilets. 2013. "War, space, and the evolution of Old World complex societies". *Proc Natl Acad Sci*. 110(41):16384–16389.

Chase-Dunn, Christopher, Richard Niemeyer, Alexis Alvarez, Hiroko Inoue and James Love. 2010. "Cycles of Rise and Fall, Upsweeps and Collapses: Changes in the Scale of Settlements and Polities Since the Bronze Age." *History and Mathematics*.Moskva: URSS.

Chase-Dunn, Christopher and Thomas Hall. 1997. *Rise and Demise: Comparing World Systems*. Westview Press.

Lenski, Gerhard. 2005. *Ecological-Evolutionary Theory: Principles and Applications*. Boulder, CO: Paradigm Publishers.