Introduction. History & Mathematics: Processes and Models of Global Dynamics

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Multidisciplinarity is one of the salient features of contemporary science. This seems to be congruent with the globalization process as the globalized world will need a "global" science that is able to integrate and to unite various fields in order to solve fundamental problems. It may be said that, in some sense, the *History & Mathematics* almanac is "genetically" interdisciplinary as it was initially designed as a means to contribute to the construction of a bridge between the humanities, social, natural, and mathematical sciences (see the *Introduction* to its first Russian issue [Гринин, Коротаев, Малков 2006: 4–11]). That time this very combination of words – *History* and *Mathematics* – might have looked a bit artificial. However, it gradually becomes habitual; what is more, it becomes to be recognized as quite an organic and important scientific phenomenon. This appears to be supported by the point that the recent two years have evidenced the publication of eight issues of the *History & Mathematics* almanac in Russian and two issues in English.[1] Various conferences in this direction are held now quite regularly, and, what is especially promising, they bring together representatives of very diverse fields of human knowledge. One of the most recent conferences of this kind was held in December 2009 in the Institute of History and Archaeology (Ekaterinburg, Russia). The conference has confirmed the existence of a critical mass of researchers within the world science that apply mathematical and quantitative methods to the study of history. Against this background the current discussions on the establishment of the *Mathematical History* academic journal do not appear coincidental.

The present issue is the third collective monograph in the series started by almanacs *History & Mathematics: Analysing and Modeling Global Development* (Grinin, de Munck, and Korotayev 2006) and *History & Mathematics: Historical Dynamics and Development of Complex Societies* (Turchin, Grinin, de Munck, and Korotayev 2006). As one can see, every issue has its own subtitle. This issue is not an exception. Its subtitle is *Processes and Models of Global Dynamics*.

[1] See Bibliography at the end of this Introduction.

The notion of "process" in one of its most wide-spread meanings denotes a certain sequence of states or phases in the change/development of something. The more ordered this sequence, the deeper its understanding, the higher the probability of the respective process to be described mathematically in a successful way, to model it (and, frequently, to use it in practical activities). That is why the constant and profound interest of our almanac in various processes is quite explicable (especially as regards major long-term processes). It is evidenced in particular by the subtitles of the first and the second English almanacs (see above).

Ashby (1958) notices that the class of systems is enormously wide, the class of processes can be well compared to the one of systems. However, within the present almanac we are naturally dealing first of all with social and historical processes. The ideas that social life is somehow connected with certain processes appeared already in antiquity – for example, ideas of constant regression (*e.g.*, from the Golden to Iron Age), or ideas of cyclical processes. The first more or less scientific historical theories were connected with the analysis of such cyclical process – here one can recollect theories of Polybius, and later Ibn Khaldūn (see, *e.g.*, Ibn Khaldūn 1958; Turchin 2003; Korotayev and Khaltourina 2006; Гринин 2010), Machiavelli, or Vico (see, *e.g.,* Гринин 2010). Theories of progress that appeared in the 18th century and flourished in the 19th century were also based on an idea of some naturally determined process, a process of constant and endless enhancement (see, *e.g.,* Turgot 1795 [1766]; Condorcet 1970 [1795]). However, the first social processes, to whose study mathematical methods started to be applied, were economic and demographic ones (see, *e.g.*, Борисов 2005).

The representation of a process in a form of a model implies a rather profound understanding of its nature, the possibility to identify regularities describing its course and (sometimes) to forecast it. That is why it is quite natural that models are present in every issue of *History & Mathematics.*

Note that the notion of "model" is used to denote a rather wide class of phenomena (Wartofsky 1979; Новик, Садовский 1988: 450). Models (and their presentation and analysis belong to the main directions of our almanac) are frequently interdisciplinary by their own nature – not least as they are still clearly linked to action, in the meaning of an active character of their elements. Mathematical models constitute just a subset of a wider set of models, but mathematical models are also extremely diverse. And our almanac is open to any of such models. Yet, we still prefer explanatory models that are capable of indentifying causes of a particular phenomenology. In addition, our almanac is based on the trends of modern post-non-classical science (see, *e.g.*, Степин 2000); we try to present such models that take into account both regular processes and such processes that go beyond the framework of repeating phenomena, such models that describe non-linear processes, chaos, phase transitions, stochastic dynamics, *etc*.

It was in very distant epochs that philosophers and thinkers tried to embrace the whole universe with a single idea; however, we feel that there is still a need for conceptually and unifyingly organizing our knowledge. As justly noticed by Erwin Schrödinger (1944), it has become almost impossible for a single mind to master more than one small specialized part of the science, but someone should still risk to attempt to synthesize facts and theories. The use of models for such generalizations facilitates significantly the respective task, as it helps to achieve (as is formulated by Hermann Haken [2006]) an enormous degree of the compression of information. Thus, we have tried to combine in the subtitle of the present issue of the almanac the most important aspects of our interests.

The contributions to the present issue study processes within very diverse spheres of social life. However, the name of our almanac is *History & Mathematics*, and it appears reasonable to consider the possible quantitative basis for an apparently unique chain of events, as history is frequently viewed. The finest shades of sounds and light can be reduced at a certain level to unified material-energetic substances/structures; similarly, historical events, processes, and phenomena that are apparently entirely different with respect to their time-scales, uniqueness, novelty, and significance have some common foundations (and what is important, those foundations may sometimes be quantified). We believe that such a common foundation of sociohistorical phenomena is constituted by the temporal nature of any historical events (see Гринин, Коротаев 2008 for more detail). But this means also that the historical time perspective is one of at least medium, more likely long-term scales (see Braudel's *longue durée*). Note that temporal vectors have the same units of measurement and are characterized by unidirectionality, whereas the latter gives to social change a character of process, as any process is a directional current of changes. Thus, we speak about some types of directionality in history, as the time itself is directional; in addition, historical processes are usually ordered by some causal logic, various positive or negative feedback loops of the first, second, or higher orders, *etc*. Due to such reasons, history is studied more and more just as a process, or, to be more exact, as a system of various processes, within which one can, for example, detect "waves", or "cycles" with various periods ranging from a few years to hundreds, or even thousands of years (see, *e.g.*, the contribution of Grinin, Korotayev, and Malkov to this volume, or Grinin 2006a, 2006b, 2007a, 2007b; Korotayev and Khaltourina 2006; Korotayev, Malkov, and Khaltourina 2006; Korotayev and Tsirel 2010).

We believe that scales, durations, degrees of orderliness/stochasticity of respective changes, their prevalence, the degree to which they are known to us, *etc*. determine to a considerable extent our conclusions about the very nature of historical development – whether it should be considered as deterministic, or stochastic; linear, or non-linear; cyclical; liable to bifurcations or so on. The more regularities can be found in various event series, the easier it is to detect fundamental similarities in various historical and social processes.

This almanac considers processes of various durations and with diverse characteristics. We have grouped them into three sections.

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The first section (titled **Analyses of the World Systems and Global Processes**) starts with *Tony Harper*'s article "The Trajectory of the World System over the Last 5000 Years" where he quantitatively delineates the non-random trajectory of the World System over the last 5000 years. A mathematical model is used to characterize the relationship between maximum urban area size and the total population of the World System at century intervals and is predicated on urban areas having a Pareto distribution. The trajectory exhibits two distinct characteristics, that of periods of oscillation punctuated by periods of continuous, directed change. At any century the position of the World System can be represented by the log-transform of $F = \alpha C - \gamma$, and it can be shown that changes in this position are brought about by changes in either $\ln\alpha$ or $\ln C_{\max}$. Also, it is shown that the trajectory is most affected by changes in the exponent, γ. Further, the World System trajectory also exhibits cyclical behavior. Other characteristics of the trajectory are also investigated.

Christopher Chase-Dunn, Richard Niemeyer, Alexis Alvarez, Hiroko Inoue, Kirk Lawrence, and *James Love* present their article "Cycles of Rise and Fall, Upsweeps and Collapses: Changes in the scale of settlements and polities since the Bronze Age". This paper uses estimates of the sizes of settlements and polities to examine patterns that need to be understood in order to explain the growing scale of human socio-cultural institutions. All systems of interacting polities oscillate between relatively greater and lesser centralization as relatively large polities rise and fall. This is true of systems of chiefdoms, states, empires and the modern system of the rise and fall of hegemonic core states. But there has also been a long-term trend in which polities have increased in population and territorial size since the Stone Age and the total number of polities has decreased. These trends have been somewhat masked in recent centuries because the processes of decolonization and the emergence of nation-states out of older tributary empires have increased the number of smaller polities. But the general trend toward larger polities can be seen in the transition from smaller to larger hegemonic core states (from the Dutch to the British and to the United States), and in the emergence of international political organizations and an expanded and active global civil society that participates in contemporary world politics.

The Lisbon performance of the countries of the European Union is analyzed from a long-term, Kornai structural perspective by *Arno Tausch*, *Almas Heshmati*, and *Chemen S. J. Bajalan* in their article "On the Multivariate Analysis of the 'Lisbon Process'". The international team of authors presents in a simple form the mathematical methods used in this essay. Then, they analyze Lisbon indicator performance by factor analytical means. Tausch, Heshmati, and Ba-

jalan conclude that only a Schumpeterian vision of capitalism as a process of "creative destruction" (or rather "destructive creation"?) can explain these contradictions, which they empirically reveal in this analysis, and which beset the "Lisbon process" from the very beginning. This factor analysis tells us that a majority of the kernel Lisbon indicators go indeed hand in hand with high comparative price levels; high transport costs; high greenhouse gas emissions; low business investment rates; and low youth educational attainment rates. The authors conclude that in reality we are facing four underlying and contradictory processes including a Lisbon productivity factor; high eco-social exclusion; the employment performance; and the neo-liberal European model.

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The second section (titled **The Models of Economic and Demographic Processes**) starts with an article by *Leonid Grinin*, *Andrey Korotayev*, and *Sergey Malkov* "A Mathematical Model of Juglar Cycles and the Current Global Crisis". The article presents a verbal and mathematical model of medium-term business cycles (with a characteristic period of 7–11 years) known as Juglar cycles. The model takes into account a number of approaches to the analysis of such cycles; in the meantime it also takes into account some of the authors' own generalizations and additions that are important for understanding the internal logic of the cycle, its variability and its peculiarities in the present-time conditions. The authors argue that the most important cause of cyclical crises stems from strong structural disproportions that develop during economic booms. These are not only disproportions between different economic sectors, but also disproportions between different societal subsystems; at present these are also disproportions within the World System as a whole.

The proposed model of business cycle is based on its subdivision into four phases:

– recovery phase (which could be subdivided into the start sub-phase and the acceleration sub-phase);

– upswing/prosperity/expansion phase (which could be subdivided into the growth sub-phase and the boom/overheating sub-phase);

– recession phase (within which one may single out the crash/bust/acute crisis sub-phase and the downswing sub-phase);

– depression/stagnation phase (which could be subdivided into the stabilization sub-phase and the breakthrough sub-phase).

The article provides a detailed qualitative description of macroeconomic dynamics at all the phases; it specifies driving forces of cyclical dynamics and the causes of transition from one phase to another (including psychological causes); a special attention is paid to the turning point from the peak of overheating to the acute crisis, as well as to the turning point from the downswing to recovery.

The proposed mathematical model of Juglar cycle takes into account the following effects that are typical for the market economy:

- positive feedbacks between various economic processes;
- presence of a certain inertia, time lags in reactions of the economic subsystem to the change in conditions;
- amplification by the financial subsystem of positive feedbacks and time lags in the economic subsystem;
- excessive reaction to changing conditions during the acute crisis subphase.

The authors suggest that the current crisis turns out to be rather similar to classical Juglar crises; however, there is also a significant difference, as the current crisis occurs at a truly global scale. Yet, due to this truly global scale of the current crisis, the possibilities of regulation with the national state's measures have turned out to be ineffective, whereas the suprastate regulation of financial processes hardly exists. It is shown that all these have led to the reproduction of the current crisis according to a classical Juglar scenario.

Michael Golosovsky presents an article titled "Hyperbolic Growth of the Human Population of the Earth: Analysis of existing models". This work focuses on 1) demographic problems arising from the growing human population of the Earth and 2) the quantitative estimates of the future growth of the Earth's population. The author discusses the existing models of the global human population growth using a popular presentation level and without appealing to so-phisticated mathematical language. Instead of proposing a new mathematical model of the population growth, Golosovsky advances a new perspective for the mathematical modeling: phase transitions which are well-know in physics. In particular, he demonstrates that the world's demographic transition is actually a phase transition that has been affecting all aspects of our life.

"A Dynamic Model of Historical Economies" by *Lucy Badalian* and *Victor Krivorotov* presents the concept of history as domestication of sequential geoclimatic zones, with clear boundaries, unique domesticated animals/plants, a dominant energy source. A zone's social institutions form a system of feeding chains uniquely adapted to its conditions. The respective mathematical model presents historical development as a fundamentally nonlinear process – imbalances start a chain of events. In this context, globalization presents a compensation for exhausted resources of the initial zone, especially, energy/food. However, the entry of periphery-suppliers is hardly seamless. Their substantial differences lead to unique local adaptations. Wars or conflicts, such as the 1870–1871 French-Prussian war or the ongoing Middle Eastern conflicts, signal of rising tensions in the search of new solutions. Below, historical examples showcase the wavelike process of imbalance generation – development in new places of signals of the exhaustion of the growth potential in the older zone. This process periodically pushes toward domesticating the next geoclimatic zone.

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The third section (titled **Cultural Dimensions**) consists of an article "The Self is not Culture: toward a unified theory of self, identity and culture" by *Victor C. de Munck* who proposes a new theory of culture that focuses on cultural models and their relationship to the self and identity. The purpose of this theory is to explicate the linkages between what goes on in the mind of individuals with a notion of cultures as shared and distributed knowledge systems. The author builds on earlier theories of cultural models by bringing the "self" back as an agent that triggers the use of cultural models. He argues that the function of the self is to give "I-ness" to various identities. Identities in turn are formed through the historical interactions in particular contexts. These interactions are mediated through cultural models. The self activates identities that are constructed and evoked by different kinds of context which we refer to as eco-niches for identities. Drawing on Simmel's work on the emergent socio-psychological properties of small groups, Victor C. de Munck posits that there are three different superordinate categories of identity which are referred to as ego-niches. There are many different kinds of basic level identities within each superordinate category and these draw on a menu of cultural models which are, in turn, used to construct contingent schemas which are then used to generate behavior. The author's theory proposes a necessary synthesis of sociocultural and psychological processes to develop a theory of the relationship between cognition and action.

Bibliography

Ashby, W. R. 1958. General Systems Theory as a New Discipline. *General Systems* 3: 1–6.

Condorcet, M. J. A. C. 1970 [1795]. *Esquisse d'un tableau historique des progrès de l'esprit humain.* Paris: Vrin.

Grinin, L. E. 2006a. Periodization of History: A Theoretic-Mathematical Analysis. *History and Mathematics: Analyzing and Modeling Global Development* / Ed. by L. E. Grinin, V. de Munck, and A. V. Korotayev, pp. 10–38. Moscow: KomKniga/URSS.

Grinin, L. E. 2006b. The Periodization of World History and Mathematics. *Fourth International Conference "Hierarchy and Power in the History of Civilizations"*. Abstracts / Ed. by D. D. Beliaev and D. M. Bondarenko, pp. 111–112. Moscow: Institute for African Studies, Russian Academy of Sciences.

Grinin, L. E. 2007a. Production Revolutions and Periodization of History: A Comparative and Theoretic-Mathematical Approach. *Social Evolution and History* 6/2: 11–55.

Grinin, L. E. 2007b. Production Revolutions and the Periodization of History. *Herald of the Russian Academy of Sciences* 77/2: 150–156.

Grinin, L., V. C. de Munck, and A. Korotayev. 2006. (Eds.). *History and Mathematics: Analyzing and Modeling Global Development*. Moscow: KomKniga/URSS.

Haken, H. 2006. *Information and Self-Organization: A Macroscopic Approach to Complex Systems*. Berlin: Springer.

Ibn Khaldūn `Abd al-Rahman. 1958. *The Muqaddimah: An Introduction to History*. New York, NY: Pantheon Books (Bollingen Series, 43).

Juglar, C. 1862. *Des Crises Commerciales et de leur retour périodique en France, en Angleterre et aux États-Unis.* Paris: Guillaumin.

Korotayev, A., and D. Khaltourina. 2006. *Introduction to Social Macrodynamics: Secular Cycles and Millennial Trends in Africa*. Moscow: KomKniga/URSS.

Korotayev, A., A. Malkov, and D. Khaltourina. 2006. *Introduction to Social Macrodynamics: Secular Cycles and Millennial Trends*. Moscow: KomKniga/URSS.

Korotayev, A., and S. Tsirel. 2010. A Spectral Analysis of World GDP Dynamics: Kondratieff Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis. *Structure and Dynamics* 4/1: 3–57.

Schrödinger, E. 1944. *What is Life? The Physical Aspect of the Living Cell*. Cambridge: Cambridge University Press.

Turchin, P. 2003. *Historical Dynamics: Why States Rise and Fall*. Princeton, NJ: Princeton University Press.

Turchin, P., L. Grinin, V. C. de Munck, and A. Korotayev. 2006. (Eds.). *History and Mathematics: Historical Dynamics and Development of Complex Societies*. Moscow: KomKniga/URSS.

Turgot, A.-R.-J. 1795 [1766]. *Reflections on the Formation and Distribution of Wealth*. London: Spragg.

Wartofsky, M. W. 1979. *Models. Representation and the Scientific Understanding*. Dordrecht – Boston – London: D. Reidel Publishing Company.

Борисов, В. А. 2005. *Демография.* 4-е изд. М.: NOTA BENE.

Гринин, Л. Е. 2010. Теория, методология и философия истории: очерки развития исторической мысли от древности до середины XIX века. *Философия и общество* 2: 151–173; 3: 162–199.

Гринин, Л. Е. и А. В. Коротаев. 2008. История и макроэволюция. *Историческая психология и социальная история* 2: 59–86.

Гринин, Л. Е., А. В. Коротаев и С. Ю. Малков. 2006. (Ред.). *История и Математика*: *проблемы периодизации исторических макропроцессов*. М.: КомКнига/URSS.

Новик, И. Б. и В. Н. Садовский. 1988. Модели в науке: исторические и социокультурные аспекты (Послесловие). *Модели. Репрезентация и научное понимание* / М. Вартофский, с. 450–484. М.: Прогресс.

Степин, В. С. 2000. *Теоретическое знание*. М.: Прогресс-Традиция.