Production Revolutions and Periodization of History: A Comparative and Theoretic-mathematical Approach*

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ABSTRACT

There is no doubt that periodization is a rather effective method of data ordering and analysis, but it deals with exceptionally complex types of processual and temporal phenomena and thus it simplifies historical reality. Many scholars emphasize the great importance of periodization for the study of history. In fact, any periodization suffers from one-sidedness and certain deviations from reality. However, the number and significance of such deviations can be radically diminished as the effectiveness of periodization is directly connected with its author's understanding of the rules and peculiarities of this methodological procedure. In this paper we would like to suggest a model of periodization of history based on our theory of historical process. We shall also demonstrate some possibilities of mathematical modeling for the problems concerning the macroperiodization of the world historical process. This analysis identifies a number of cycles within this process and suggests its generally hyperexponential shape, which makes it possible to propose a number of forecasts concerning the forthcoming decades.

When we speak about some global general theories, like macroperiodization of the world historical process, any figures, cycles, diagrams and coefficients, of course, cannot prove too much by themselves. Especially, if the respective analysis includes ancient periods for which all the figures are likely to be too much approximate and unreliable. Thus, for general theories covering im-

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mense distances in time and space, the main proves are a good empirical basis, logics, internal consistency and productivity of theoretical constructions; that is, a theory's ability to explain the facts better than other theories do. On the other hand, any theory is better when it is supported by more arguments. Mathematical proofs can be rather convincing (when they are relevant, of course). This is especially relevant with respect to those aspects that are more liable to mathematical analysis, for example, those connected with demography.

In this article we have chosen such an aspect that is liable to mathematical analysis and quite suitable for it. This is the *temporal* aspect of history. Its suitability for mathematical analysis is connected with the following: though it is quite possible to speak about the tendency of historical time toward acceleration (and this is the subject of the present article), the astronomic time remains the same. Thus, within this study we have a sort of common denominator that helps to understand how the 'numerator' changes. Hence, we believe that for the analysis of the periodization of history the application of mathematical methods is not only possible, but it is also rather productive.

Many scholars emphasize the great importance of periodization for the study of history (*e.g.*, Jaspers 1953; Green 1992, 1995; Gellner 1988; Bentley 1996; Stearns 1987; McNeill 1995; Manning 1996; Goudsblom 1996; White 1987; Diakonoff 1999; Ershov 1984; Zhigunin 1984; Pavlenko 1997, 2002; Rozov 2001a, 2001b; Semenov 1999; Korotayev 2006). Gurevich emphasizes that 'the human thought cannot avoid dividing the historical process into definite periods' (2005: 681). There is no doubt that periodization is a rather effective method of data ordering and analysis, but it deals with exceptionally complex types of processual, developmental and temporal phenomena and thus, it simplifies historical reality. This might be the reason why some scholars belittle the role of periodization and some of them even directly oppose the notion of process and stages as mutually exclusive (see, *e.g.*, Shanks and Tilley 1987; see also Marcus and Feinman 1998: 3; Shtompka 1996: 238). One may agree that the contraposition of process and stages is a false dichotomy (Carneiro 2000) because stages are continuous episodes of a continuous process, and the notion of process can be used for the development of the notion of stages (Goudsblom 1996).

In fact, any periodization suffers from one-sidedness and certain deviations from reality, but as Jaspers noted, '…the purpose of such simplifications is to indicate the essentials' (1953: 24). Moreover, the number and significance of such deviations can be radically diminished as the effectiveness of periodization is directly connected with its author's understanding of the rules and peculiarities of this methodological procedure (for more detail on these procedures see Grinin 1998b: 15–28; 2003a: 67–78; 2003b: 219–223; 2006a; 2006b; 2007a; see also Shofman 1984). Unfortunately, insufficient attention is paid to these issues (and periodization problems in general), which leads to serious problems. In particular, to develop a periodization one needs to observe the rule of the 'single basis', that is, to use the same criteria for the identification of periods with the same taxonomical significance, whereas many periodizations are not based on rigorous criteria, or the applied criteria are eclectic and change from one stage to another (*e.g.*, Green 1995), or the scholars just base themselves on the following scheme: Antiquity – Middle Ages – Modern Age (see Green 1992).

The second point is how well the periodization bases are reasoned, and how they are connected with a scholar's general theory, as well as with the goal of periodization. Different scholars choose different bases for periodization, ranging from changes in the types of ideas and thinking (*e.g.*, Comte 1974 [1830−1842]; Jaspers 1953) to ecological transformations (Goudsblom 1996) and intercultural interaction (Bentley 1996). Many scholars, ranging from the 18th century thinkers (Turgot, Barnave, Ferguson, Smith) to modern postindustrialists like Bell (1973) and Toffler (1980), base themselves on economic and technological criteria. Two extremes can be observed depending on the choice of criteria. Too often, when scholars ascribe absolute meaning to the chosen factors, in Pitirim Sorokin's words (Sorokin 1992: 522), 'they turn out to be partially right, but one-sidedly wrong at the same time'. Some do not think at all about the connection between periodization and theory (on this issue see Stearns 1987; Bentley 1996), or periodization is used as a sort of 'headband' for the main theory (*e.g.*, Toffler 1980).

In this article we suggest a model of periodization of historical process based on our theory of historical process. The full conceptual and methodological justification for this periodization can be found in our earlier publications (see Grinin 1998b, 2000, 2003a, 2003b, 2006b, 2007a). Thus, here we shall concentrate on a brief description of the essence and chronology of periodization; we shall also demonstrate the possibilities of mathematical modeling of temporal processes and temporal cycles in historical development. It is important to state the following reservation: this periodization can only be applied to world historical process (further denoted as 'historical process') and to a considerable (but not to the full) degree to the evolution of World-System (interpreting it after the manner of Andre Gunder Frank [Frank 1990; 1993; Frank and Gills 1993; Korotayev, Grinin 2006]). Thus, the given periodization refers only to macroevolutionary processes, and therefore can be directly applied to the histories of particular countries and societies only by means of special and rather complicated methodological procedures. Its task is to define a scale for measurement of processes of the development of humankind and to mark possibilities for intersocietal comparison.

A few words are necessary in order to clarify our understanding of the 'historical process' notion (for more detail see Grinin 2003a). The first point to be made is that this notion is in no way synonymous with 'world history'[1]. Of course, the notion of historical process is based on world history facts, but firstly, there have been chosen only those facts that are the most important from the point of view of process and changes; secondly, this set of facts has been ordered and interpreted in accordance with the analyzed spatial and temporal scales, trends and logics of historical development of humankind as a whole, as well as the present-day results of this development. In other words, historical process is in no way a mechanical sum of the histories of numerous peoples and societies, it is not even just the process of temporal movement and development of these people and societies. The historical process is a growing and even cumulative process of societal integration that has a certain direction and result. The notion of the historical process of **humankind** does not imply that humankind has always been a real system. It implies the following: **(a)** that we select a respective scale for our analysis; **(b)** that we take into account the fact that throughout all the periods of the historical process societies, civilizations and its other subjects have been developing unevenly, *i.e.* at a different rate of social progress. Among other things from the methodological point of view it indicates that for the analysis of historical process the most important role is played by the model of the influence produced by more developed regions on the less developed ones; **(c)** the interaction scale expands from one period to another until it reaches the scale of the whole planet; **(d)** hence, the historical process of humankind is, first of all, a process of movement from autonomous and isolated social minisystems towards the formation of the present extremely complex system of intensely interacting societies; **(e)** when (and if) humankind gets transformed into a subject whose development as a whole is determined (at least partially) by a general and explicitly expressed collective will, the historical process in its current meaning will come to its end, and this will lead to a transition to a new generation of processes.

Thus, historical process is a notion that generalizes an intricate complex of internal transformations and actions of various historical subjects, as a result of which important societal changes and integration, continuous enlargement of intersocietal systems take place, transition to the new levels of development is going on, and in general (taking into consideration the present results and future perspectives), humankind gets transformed from a potential unity into an actual one.

Of course, this definition of historical process is rather conventional; however, it has a considerable heuristic potential and makes it possible to construct generalizing theories. The critics of the notion 'world history process' rely on the idea that humankind is not a system that can be regarded as a real subject, that the history of humankind is the history of particular societies; thus, it is impossible to speak about the historical process of humankind (see, *e.g.*, Miljukov 1993 [1937] 43–47; Hotsej 2000: 488–489). In the meantime it becomes more and more evident that the globalization process is making (and, in some respects, has already made) humankind a real subject. But if humankind is becoming a real supersystem and the process of this system's structuralization starts producing more and more tangible results, then why is it impossible to study the historical process of the humankind system formation? If it is possible to study the dynamics of world population as well as some other world characteristics and to develop theories and periodizations on this basis (*e.g.*, Kapitza 2004a; Korotayev, Malkov, and Khaltourina 2006a, 2006b), why is not it reasonable to speak about the historical process of the humankind as a whole? And, for example, McNeill (2001: 1) suggests that historians should 'make a sustained effort to enlarge the views and explore the career of humankind on earth as a whole'.

Quite often the notion of *humankind* is actually substituted with some other notions, like *civilizations*, starting from Danilevsky (Danilevskij 1995 [1869]), Spengler (1939), Toynbee (1962−1963), and ending with Huntington (Huntington 1994), or *the World System* (Frank 1990, 1993; Frank and Gills 1993; Korotayev, Malkov, and Khaltourina 2006a, 2006b). We believe that such notions can be of much use, but only at a certain level and in certain aspects of analysis. And, of course, they differ from the notion of *humankind* both temporally (as all the pre-agrarian epoch and the early agrarian period are left outside their limits) and spatially (if we do not try to make one notion a full synonym of the other). The attempts to substitute the notion of humankind with any other, less encompassing, notions are basically attempts to prohibit any research at a higher level of generalization; this is just a substitution of one level of research with another, narrower one[2].

According to the theory that we propose, the historical process can be subdivided more effectively into four major stages or four formations of historical process. The transition from any of these formations into another is tantamount to the change of all the basic characteristics of the respective formation. However, in addition to this principle basis of periodization (that determines the number of singled out periods and their characteristics), we need an additional basis, by means of which the chronology may be worked out in detail[3].

As such an additional basis we have proposed the *production principle* (Grinin 1995–1996, 2000, 2003a, 2007a) that describes the major qualitative stages of the development of the world productive forces[4]. We single out four **production principles**:

1. **Hunter-Gatherer.**
2. **Craft-Agrarian.**
3. **Industrial.**
4. **Information-Scientific.**

Though the qualitative transformations in some spheres of life are closely connected with changes in the other (and, thus, no factors can be considered as absolutely dominant), some spheres (with respect to their influence) can be considered as more significant;

that is, changes within them are more likely to lead to the changes in the other spheres than the other way round[5]. The production principle belongs to such spheres due to the following reasons:

1. Significant changes in the production basis lead to the production of more surplus and to the rapid growth of population. And both these processes lead to changes in all other spheres of life. Still the transition to new social relations, new religious forms *etc.* is not as directly connected with the demographic changes as are the transformations of the production principle.

2. Though a significant surplus can appear as a result of some other causes (natural abundance, successful trade or war), such exceptional conditions cannot be borrowed, whereas new productive forces can be borrowed and diffused, and thus, they appear in many societies.

3. Production technologies are applied by the whole society (and what is especially important, by the lower social strata), whereas culture, politics, law, and even religion are systems developed by their participants (usually the elites)[6].

The change in production principles is connected with production revolutions. The starting point of such revolutions can be regarded as a convenient and natural point from which the chronology of formation change can be established.

The production revolutions are the following: **1) the Agrarian Revolution** (the 'Neolithic Revolution'); **2) the Industrial Revolution; 3) the Information-Scientific Revolution**. The production revolutions as technological breakthroughs have been discussed for quite a long time. The Industrial Revolution became an object of extensive research already in the 19th century[7]. The first ideas on the Neolithic (Agrarian) Revolution appeared in the works of Gordon Childe in the 1920s and 1930s, and the theory of this revolution was developed by him in the 1940s and 1950s (Childe 1948, 1949, 1952). In connection with the Information-Scientific Revolution which started in the 1950s the interest in the study of production revolutions significantly increased. However, the category 'production revolution' has not been sufficiently worked out and its contents are determined in a predominantly intuitive way. A lot has been written about each of the three production revolutions (see, *e.g.*: Reed 1977; Harris and Hillman 1989; Cohen 1977; Rindos 1984; Smith 1976; Cowan and Watson 1992; Ingold 1980;

Cauvin 2000; Knowles 1937; Dietz 1927; Henderson 1961; Phyllys 1965; Cipolla 1976a; Stearns 1993, 1998; Lieberman 1972; Mokyr 1985, 1993; More 2000; Bernal 1965; Philipson 1962; Benson and Lloyd 1983; Sylvester and Klotz 1983); however, there is a surprisingly small number of studies concerning these revolutions as recurrent phenomena, each of which represents an extremely important landmark in the history of humankind (*e.g.*, Vasil'ev 1977: 8; Cipolla 1976b: 7; Gellner 1983, 1988). What is more, most of these studies are fragmentary and superficial. On the other hand, we have developed a theory of production revolution (Grinin 1995–1996, 2000, 2003a, 2006a, 2007a, 2007b) in the framework of the overall theory of a pan-human historical process.

The production revolution can be defined as a radical turn in the world productive forces connected with the transition to the new principle of management not only in technologies but in the interrelations of society and nature. The distinction of the production revolution from various technical overturns is that it touches not only some separate essential branches but the economy on the whole. And finally, the new trends of management become dominant. Such an overturn involves in the economical circulation some fundamentally new renewable or long inexhaustible resources, and these resources must be widespread enough within most territories; it rises labor productivity/ or land carrying capacity (the yeild of useful product per unit of area) by orders of madnitude; this is also expressed in the creation of several orders greater volume of production and the demographic revolution.

As a result, the most powerful impulse for qualitative reorganization of the whole social structure is generated. Although the production revolution begins in one or a few places but as it signifies the turn of the *world* productive forces, it represents a long lasting process gradually involving more and more societies and territories. As a result a) the societies where it took place become progressive in a technological, economical, demographical, cultural and often military aspects; b) the break with new production system is an exception while joining it becomes a rule.

Each production revolution has its own cycle. We can speak about two qualitative phases and a quantitative phase between them that can be regarded as a sort of interruption between the qualitative phases. Each phase of a production revolution represents a major breakthrough in production[8]. During the first phase the new production principle hotbeds are formed; those sectors that concentrate the principally new production elements grow in strength. Then the qualitatively new elements diffuse to more societies and territories. In those places where the most promising production version has got formed and adequate social conditions have appeared the transition to the second phase of production revolution occurs, which marks the flourishing of the new production principle. Now underdeveloped societies catch up with the production revolution and become more actively engaged in it. Thus, we confront a certain rhythm of the interchange of qualitative and quantitative aspects. A general scheme of two phases of production revolution within our theory looks as follows:

Agrarian Revolution: the **first phase** – transition to primitive hoe agriculture and animal husbandry; the **second phase** – transition to intensive agriculture (especially to irrigation or non-irrigation plough one).

Industrial Revolution: the **first phase** starts in the 15th and 16th centuries with the vigorous development of seafaring and trade, mechanization on the basis of water engine, the deepening division of labor and other processes. The **second phase** is the industrial breakthrough of the 18th century and the first third of the 19th century which is connected with the introduction of various machines and steam energy.

Information-Scientific Revolution: the **first phase** began in the 1940s and 1950s with breakthroughs in automation, power engineering, production of synthetic materials, but especially in the development of electronic means of control, communication and information. However, it appears possible to speak about its forthcoming **second** phase (see, *e.g.*, Marahov 1984: 314; Grinin 2003a)[9] which may start within a few decades.

We believe that the production revolution can be regarded as an integral part (the first 'half') of the production principle. Thus, the overall cycle of the production principle can be represented in two phases: first is the production revolution which is followed by the development of mature relations). Such an approach demonstrates in a rather explicit way the main 'intrigue' of the cyclical pattern of historical formations. In their first half we observe mostly the radical production changes, whereas in the second half we deal with especially profound changes of political and social relations, public consciousness and other spheres. Within these periods, on the one hand, political-judicial and sociocultural relations catch up with more developed production forces, and, on the other hand, they create a new level, from which an impulse toward the formation of a new production principle starts[10].

However, a production principle cycle can be also represented in a classical three-phase fashion: *formation, maturity, and decline*. Yet, in some sense it appears more convenient to represent it in 6 phases, each pair of which demonstrates an additional rhythm of change of qualitative and quantitative characteristics. Such a cycle looks as follows:

1. The first phase – 'transitional'. It is connected with the beginning of the production revolution and the formation of a new production principle in one place, or a few places, however, in rather undeveloped and imperfect forms.

2. The second phase – 'adolescence' – is connected with a wider diffusion of new production forms, with the strengthening and vigorous expansion of the new production principle. A new formation (or World System) appears.

3. The third phase – 'florescence' – is connected with the second phase of the production revolution, as a result of which a basis for the mature forms of the production principle is developed.

4. The fourth phase – 'maturity' – is connected with the diffusion of new technologies to most regions and production branches. The production principle acquires its classical forms. It is in this phase when particularly important changes start in non-production spheres as it was mentioned above.

5. The fifth phase – 'high maturity' – leads to the intensification of production, the realization of its potential almost to the limit, after which crisis phenomena become to appear; that is, non-system (for the given production principle) elements begin to emerge.

6. The sixth phase – 'preparatory'. Intensification grows, more and more non-system elements that prepare the formation of a new production principle emerge. However, they do not form a system yet. After this in some societies a transition to a new production principle can take place, and a new cycle begins.

The correlation between phases of production principles and phases of production revolutions is spelled out in Figure 1.

Let us consider now our chronology of the production principles, production revolutions, and their phases. It starts from the period about 40,000−50,000 years ago (but to facilitate our calculation we take the younger date of 40,000 years ago), that is, since the appearance of the first indisputable indications of truly human culture and society[11]. To understand the reason for the choice of precisely this landmark one should take into consideration that any periodization must have some conceptual and formal unity at its basis. In particular, we believe that it is possible to speak about a social evolution in its proper sense only since the time when social forces became the basic driving forces for the development of human communities. We suppose that one should include in the era of anthropogenesis, not only that long period of time when our ape-like ancestors (Ingold 2002: 8) were gradually obtaining an anatomical resemblance to modern human beings (that is approximately till 100–200 thousand years ago), but the subsequent rather long period (that lasted for many thousands of years) when those creatures anatomically similar to us were becoming *Homo sapiens sapiens,* that is becoming people in their intellectual, social, mental and language development. Of course, during this second phase of anthropogenesis the role of social forces in the general balance of driving forces was much larger than it was during the first phase. However, we believe that in general, during the whole process of anthropogenesis the driving forces were primarily biological, and only to a rather small degree were they social. Of course, it was a very long process and one cannot point out a definite point when a crucial change tool place (as most likely in a literal sense there was not such a radical turn). Nevertheless we believe that after reaching the above-mentioned landmark of 40,000−50,000 years ago the social component of the evolutionary driving forces became dominant. We also believe that for these same reasons it is not possible to speak about humankind as a set of societies before this time. Thus, the notions that serve as a basis for our periodization – *formations of historical process* and *production principles* – cannot be applied to the periods prior to 40,000−50,000 years ago. Thus, our periodization starts with the most important production revolution for humankind; what is more, people themselves are, undoubtedly, part of the productive forces[12].

Due to the paucity of information on the first formation it appears reasonable to connect the phases of the hunter-gatherer production principle with the qualitative landmarks of human adaptation to nature and its acquisition. Indeed, during this period community size, tools, economic forms, lifestyles – that is, practically everything – depended almost exclusively on the natural environment. If we correlate phases with major changes in environment, it appears possible to connect them with an absolute chronology on a panhuman scale. This appears especially justified, as in accordance with the proposed theory a part of the natural environment (within a theoretical model) should be included in the productive forces, and the more they are included, the weaker their technological component (see Grinin 2000, 2003a, 2006c). Such approaches have not been developed quite yet; but indications of such an approach appeared quite a long time ago (*e.g.*, Kim 1981: 13; Danilova 1981: 119; Anuchin 1982: 325; Kulpin 1990, 1996).

The **first** phase may be connected with the 'Upper Paleolithic' Revolution and the formation of social productive forces (however primitive they were at that time). Already for this period more than 100 types of tools are known (Boriskovskij 1980: 180). The **second** phase (approximately and very conventionally, 30,000–23,000 [20,000] BP) led to the final overcoming of what may be called the residue contradiction of anthropogenesis: between biological and social regulators of human activities. This phase is connected with the wide diffusion of people, the settlement in new places, including the peopling of Siberia (Doluhanov 1979: 108) and, possibly, the New World (Zubov 1963: 50; Sergeeva 1983), though the datings here are very scattered (Sergeeva 1983).

The **third** phase lasted till 18,000 – 16,000 BP. This is the period of the maximum spread of glaciers (referred to as the glacial maximum)[13]. And though this was not the first glaciation, this time humans had a sufficient level of productive forces and sociality so that some groups managed to survive and even flourish within those severe conditions. Large changes took place with respect to variety and quantity of tools (Chubarov 1991: 94). This is precisely the time when there occurred a fast change of types of stone tools; for example, in France (Grigor'ev 1969: 213), in the Levant (18,000 BP) microliths appeared (Doluhanov 1979: 93). During this phase, as well as the subsequent **fourth** phase – *c.* 17,000–14,000 (18,000–15,000) BP – the level of adaptation to the changing natural environment significantly increased. In some places that lacked glaciation, intensive gathering appeared (Hall 1986: 201; Harlan 1986: 200).

The **fifth** phase – 14,000–11,000 (15,000–12,000) BP, that is the end of the Paleolithic and the beginning of the Mesolithic (Fajnberg 1986: 130) – may be connected with the end of glaciation and climate warming (Jasamanov 1985: 202–204; Koronovskij, Jakushova 1991: 404–406). As a result of this warming and consequent change in the landscape the number of large mammals decreased. That is why a transition to individual hunting was observed (Markov 1979: 51; Childe 1949: 40). Technical means (bows, spear-throwers, traps, nets, harpoons, new types of axes *etc.*) were developed for the support of autonomous reproduction of smaller groups and even individual families (Markov 1979: 51; Prido 1979: 69; Avdusin 1989: 47). Fishing in rivers and lakes was developed and acquired a major importance (Matjushin 1972). The **sixth** phase (*c.* 12,000–10,000 BP) was also connected with continuing climatic warming, environmental changes culminating in the transition to the Holocene (see, *e.g.*, Hotinskij 1989: 39, 43; Wymer 1982 [and archaeologically – to the Neolithic in connection with considerable progress in stone industries]). This period evidenced a large number of important innovations that, in general, opened the way to the new, craft-agrarian, production principle (see, *e.g.*, Mellaart 1975). Of special interest are harvest-gathering peoples who were a potentially more progressive development of the craft-agrarian branch. Such gathering can be very productive (see, *e.g.*, Antonov 1982: 129; Shnirel'man 1989: 295–296; Lips 1956; Lamberg-Karlovsky, Sabloff 1979).

Whatever plants were cultivated, the independent invention of agriculture always took place in special natural environments (see, *e.g.*, [Deopik 1977: 15] with respect to South-East Asia). Correspondingly, the development of cereal production could only take place in certain natural and climatic environments (Guljaev 1972: 50–51; Shnirel'man 1989: 273; Mellaart 1982: 128; Harris and Hillman 1989; Masson 1967: 12; Lamberg-Karlovsky, Sabloff 1979). It is supposed that the cultivation of cereals started somewhere in the Near East: in the hills of Palestine (Mellaart 1975, 1982), in the Upper Euphrates area (Alekseev 1984: 418; Hall 1986: 202), or Egypt (Harlan 1986: 200). The beginning of the agricultural revolution is dated within the interval 12,000 to 9,000

BP, though in some cases the traces of the first cultivated plants or domesticated animals' bones are even of a more ancient age of 14–15 thousand years ago. Thus, in a rather conventional way it appears possible to maintain that the **first** phase of the craft-agrarian production principle continued approximately within the interval from 10,500 to 7,500 BP (the 9th–6th millennia BCE). This period ends with the formation of the West Asian agricultural region, and on the whole one may speak about the formation of the World-System during this period, also including its first cities (about cities see Lamberg-Karlovsky, Sabloff 1979; Masson 1989).

The **second** phase can be conventionally dated to 8000–5000 BP (the 6th – mid-late 4th millennia BCE), that is up to the formation of a unified state in Egypt and the development of a sophisticated irrigation economy in this country. It includes the formation of new agricultural centers, diffusion of domesticates from West Asia to other regions. The husbandry of sheep, goats and the first draught animals is developed. The active interchange of achievements (domesticates and their varieties, technologies, *etc.*) is observed. During this period (starting from the 5th millennium BCE) the first copper artifacts and tools appeared in Egypt and Mesopotamia (and a bit later in Syria) (Tylecote 1976: 9). According to Childe the so-called urban revolution took place at that time (Childe 1952, ch. 7; see also Lamberg-Karlovsky, Sabloff 1979; Masson 1989; Oppenheim 1968).

During the **third** phase, 5000–3500 (5300–3700) BP, *i.e.* 3000–1500 BCE agriculture starts; animal husbandry, crafts and trade are differentiated into separate branches of economy. Though, according to our theory, crafts did not determine the development of agricultural revolution, it appears necessary to note that, according to Chubarov's data at the end of the second phase and the beginning of the third a very wide diffusion of major innovations (wheel, plough, pottery wheel, harness [yoke], bronze metallurgy, *etc.*) is observed (Chubarov 1991; see also about plough McNeill 1963: 24−25; on bronze metallurgy Tylecote 1979: 9). This was the period when the first states, and later empires, appeared in the Near East. Urbanization also went on encompassing new regions. This period ends with a major economic, agrotechnical, and craft upsurge in Egypt at the beginning of the New Kingdom (Vinogradov 2000).

The **fourth** phase (3500–2200 [3700–2500] BP, or 1500–200 BCE) is the period when systems of intensive (including non-irrigation plough) agricultures formed in many parts of the world. We observe an unprecedented flourishing of crafts, cities, trade, formation of new civilizations and other processes that indicate that the new production principle began to approach its maturity. This phase lasts till the formation of new gigantic world states from Rome in the West till China in the East, which later led to major changes in productive forces and other social spheres.

The **fifth** phase (the late 3rd century BCE – early 9th century CE) is the period of the most complete development of the productive forces of the craft-agrarian economy, the period of flourishing and disintegration of the ancient civilizations and formation of civilizations of a new type (Arab, European etc.).

The **sixth** phase (from the 9th century till the first third of the 15th century). At its beginning one can see important changes in the production and other spheres in the Arab-Islamic world and China; in particular, in the second half of the 1st century BC the wide international trade network from the East African Coast to South-East Asia and China developed in the Indian Ocean basin (Bentley 1996). Then we observe the beginning of urban and economic growth in Europe, which finally creates first centers of industry and preconditions for industrial revolution.

The first phase of the industrial revolution (and, respectively, the **first** phase of the industrial production principle) may be dated to the period lasting from the second third of the 15th century to the late 16th century[14]. Included in this phase are those types of activities that were both more open to innovation and capable of accumulating more surplus (trade [Mantu 1937: 61–62; Bernal 1965] and colonial activities [Baks 1986], which had become more and more interwoven since the 16th century) came to the forefront. Besides, at that time, primitive industries (but still industries) developed in certain fields. It is during this period when according to Wallerstein (1974, 1980, 1988; 1987) the capitalist world-economy was formed.

From the late 16th century to the first third of the 18th century there lasted the**second** phase (**adolescence**) of the new production principle, a period of growth and development of new sectors that had become dominant in some countries (the Netherlands and England).

The **third** phase of the industrial production principle began in the second third of the 18th century in England. It meant the beginning of the second phase of the industrial revolution that led to the development of the machine-based industries and the transition to steam energy. Supplanting handwork with machines took place in cotton textile production that developed in England (Mantu 1937: 184). Watt's steam engine started to be used in the 1760s and 1770s. A new powerful industry – machine production – had developed. The industrial breakthrough was more or less finalized in England in the 1830s. The successes of industrialization were evident in a number of countries by that time and it was also accompanied by significant demographic transformations (Armengaud 1976; Minghinton 1976: 85–89).

The **fourth** phase (from the 1830s to the late 19th century) is the period of the victory of machine production and its powerful diffusion. The **fifth** phase took place in the late 19th century − the early 20th century up to the world economic crisis of the late 1920s–1930s. During that period there occurred huge changes. The chemical industries experienced vigorous development, a breakthrough was observed in steel production, the extensive use of electricity (together with oil) gradually began to replace coal. Electrical engines changed both the factories and everyday life. Development of the internal combustion engines led to the wide diffusion of automobiles. The **sixth** phase continued till the mid 20th century. A vigorous intensification of production and the introduction of scientific methods of its organization took place during this period. There was an unprecedented development of standardization and the enlargement of production units. Signs of the forthcoming information-scientific revolution became more and more evident.

The production revolution that began in the 1940s and 1950s and continues up to the present is sometimes called the 'scientific-technical' revolution (*e.g.*, Benson and Lloyd 1983). However, it would be more appropriate to call it the 'information-scientific' revolution, as it is connected with the transition to scientific methods of production and circulation management. Especially important changes have taken place in information technologies. In addition, this production revolution had a few other directions: in energy technologies, in synthetic materials production, automation, space exploration, and agriculture. However, its main results are still forthcoming.

The information-scientific production principle (and the fourth formation in general) is only at its beginning; only its first phase has been finished and the second phase has just started. Hence, all the calculations of the forthcoming phases' lengths are highly hypothetical. These calculations are presented in Tables 1 and 2.

The **first** phase of the information-scientific production principle took place between the 1950s and mid 1990s, when a vigorous development of information technologies and the start of real economic globalization were observed. The **second** phase began in the mid 1990s in conjunction with the development and wide diffusion of user-friendly computers, communication technologies and so on. It continues up to the present.

The **third** phase may begin approximately in the 2030s – 2040s. It will mean the beginning of the second phase of the information-scientific revolution that in our view may become a **'control system' revolution**, that is, the vast expansion of abilities to purposefully influence and direct various natural and production processes (see Grinin 2000, 2003a, 2006a). Judging by the recent scientific, biotechnological and medical inventions (in particular, within *nanotechnologies*), the second phase of this revolution may start with changing human biological nature. There is a great number of various suppositions concerning changes of that kind, they are dealt with by intellectuals in different fields starting from philosophers to fantasists (see, *e.g.*, Fukuyama 2002; Sterling 2005).

For the expected lengths of the **fourth, fifth,** and **sixth** phases of the information-scientific production principle see Table 1. In general, it may end by the end of this century, or by the beginning of the next one. This implies an immense acceleration of development that can be hardly compatible with the biopsychic human nature. Indeed, in view of the growing life expectancies all the immense changes (the 2040s to 2090s) will happen within the span of one generation that will appear in the 2010s. The significance of these changes will be no smaller (what is more, it is likely to be greater) than the significance of the ones that took place between 1830 and 1950 that included gigantic technological transformations, the transition from agricultural to industrial society, social catastrophes and world wars. However, these metamorphoses took place within 120 years, whereas the expected period of the forthcoming transformation is twice as short. And if they occur within a lifespan of one generation, it is not clear whether human physical and psychic capabilities will be sufficient to stand this; what price will be paid for such a fast adaptation? Thus, we confront the following question: how could the gap between the development of productive forces and other spheres of life be compensated?[15]

Now we can start our mathematical analysis of the proposed periodization. Mathematical methods are quite widely used in historical research, but, unfortunately, mathematical studies of historical periodization are very few indeed[16]. In the meantime the discovery of mathematical regularities within an existing periodization may serve as a confirmation of its productivity and as a basis for tentative forecasts. *Time* as a parameter of historical development is quite suitable for mathematical analysis, for example, economic and demographic historians study actively temporal cycles of various lengths[17]. Cycles used as a basis for this periodization are not different in any principal way from the other temporal cycles with regard to the possibility of being subject to mathematical analysis.

Table 1 ('Chronology of Production Principle Phases') presents dates for all the phases of all the production principles. However, it should be taken into account that in order to make chronology tractable all the dates are approximated even more than the ones used in the text above. Table 2 ('Production Principles and Their Phase Lengths') presents the absolute lengths of the phases in thousands of years. Table 3 ('Ratio of Each Phase [and Phase Combination] Length to the Total Length of Respective Production Principle [%%]') presents results of our calculations of the ratio of each phase's length to the length of the respective production principle using a rather simple methodology[18]. Table 4 ('Comparison of Phase Length Ratios for Each Production Principle [%%]') employs an analogous methodology to compare lengths of phases (and combinations of phases) within one production principle. For example, for the hunter-gatherer production principle the ratio of the first phase length (10,000 years) to the second (8,000 years) equals 125 %; whereas the ratio of the second phase to the third

(5,000 years) is 160 %. In the meantime the ratio of the sum of the first and the second phases' lengths to the sum of the third and the fourth (3,000 years) phases equals 225 %. Tables 3 and 4 also present the average rates for all the production principles.

Thus, the proposed periodization is based on the idea of recurrent developmental cycles (each of them includes six phases); however, each subsequent cycle is shorter than the previous one due to the acceleration of historical development. No doubt that these are recurrent cycles, because within each cycle in some respect development follows the same pattern: every phase within every cycle plays a functionally similar role; what is more, the proportions of the lengths of the phases and their combinations remain approximately the same (see Tables 3 and 4). All this is convincingly supported by the above mentioned calculations, according to which with the change of production principles stable proportions of the lengths of phases and their combinations remain intact.

In general, our mathematical analysis represented in diagrams and tables below indicates the following points: a) evolution of each production principle in time has recurrent features, as is seen in Diagrams 1–4; b) there are stable mathematical proportions between lengths of phases and phase combinations within each production principle (Tables 3 and 4); c) the cycle analysis clearly indicates that the development speed increases sharply just as a result of production revolutions (see Diagram 5); d) if we calibrate the Y-axis of the diagram[19], the curve of historical process acquires a hyperbolic (Diagram 6) rather than exponential shape (as in Diagrams 1–4), which indicates that we are dealing here with a blow-up regime (Kapitza, Kurdjumov, and Malinetskij 1997).

The analysis of stable proportions of production principle cycles makes it possible to propose some tentative forecasts (in particular, with respect to the lengths of the remaining phases of the fourth production principle)[20].

And the last comment. The historical process curve (see Diagram 6) might look a bit embarrassing, as it goes to infinity within a finite period of time. In this respect Diakonoff (1999: 348) notes the following:

> As applied to history, the notion [of infinity] seems to make no sense: the succession of Phases, their development ever more rapid, cannot end in changes taking place

> every year, month, week, day, hour or second. To avoid a catastrophic outcome – let us hope that wise *Homo Sapiens* will find a way – then we have to anticipate intervention from as yet unknown forces.

However, it should be taken into account that the diagram depicts the development of just one variable of the historical process – the technological one, whereas the high correlation between general development and technological development is observed within certain limits. Outside these limits various deviations (both with respect to the development vectors and its speed) are possible. First of all, it is quite evident that the general development of the system does not catch up with the technological one; secondly, the growing gap implies that the price for progress will grow too. In other words, uncontrolled scientific-technological and economic changes lead to the growth of various deformations, crisis phenomena in various spheres of life, which slows down the overall movement and in many respects changes its direction. Actually, if the system persists, the overall speed of its development cannot exceed the speed of the least dynamic (most conservative) element (for example, ethnic, or religious-ideological consciousness, or morals) whose change needs the change of generations. The growth of the system gaps in connection with changing economic, information, and technological realities can lead to its breakdown and its replacement with another system. And the price paid for such a rapid transformation of such an immensely complex system as modern humankind may be very high indeed.

NOTES

* This paper is based on a presentation at the Third General Scholarly Meeting of the Society for Anthropological Sciences (SASci). San Antonio, Texas. February 21–24, 2007.

[1] However, even the very notion of 'world history' and 'universal history', though it is recognized as an important concept by a number of scholars (*e.g.*, Ghosh 1964; Pomper 1995; Geyer and Bright 1995; Manning 1996), it had been considered as a rather useless concept for a long time by historians and social scientists, and even now it is not recognized by many of them (see Pomper 1995; Geyer and Bright 1995). But what is the most important is that 'while historians increasingly recognize the importance of world history, they remain relatively ignorant about it as a developing field' (Pomper 1995: 1).

[2] These attempts have a long history. For example, Miljukov (1993 [1937]: 43–47) declared the world historical view obsolete and insisted that the natural unit of scientific observation is nothing else but a 'national organism'.

[3] Generally speaking, this point is especially important methodologically, as it accounts for the cyclical nature of the 'unfolding' of the above mentioned stages/formations. The development of some spheres inevitably leads to the accumulation of changes in the other spheres till a radical transformation occurs within them that leads to the accumulation of non-system incongruences in the former. Thus, causes and effects constantly interchange their places, that is why it turns out to be impossible to speak about any absolutely dominant spheres; it appears more productive to consider some spheres as relatively dominant.

[4] This notion is not identical with the Marxist 'mode of production', because firstly, 'mode of production' includes both the productive forces and the relations of production, whereas its change is connected with the change in the property relationships. The 'production principle' only characterizes the changes in production and is connected with production revolutions. Secondly, the mode of production notion can be applied both to separate societies and to the historical process, whereas the production principle is a category that only describes the world production forces (for more detail see Grinin 2003a: 30–47).

[5] Of course, we do not mean continuous and regular influence; we rather mean the moments of qualitative breakthrough. If after a breakthrough within a more fundamental sphere the other spheres do not catch up with it, the development within the former pauses.

[6] Sergey Malkov (2006) shows what changes take place in societies with the change of each production principle and develops mathematical models describing the functioning of a typical society for each production principle (except the information-scientific one). These models suggest that the change in our periodization basis, the production principle, does lead to a total change of all the main societal characteristics and to the humankind transition to a qualitatively new development stage (see also Malkov 2004, 2005).

[7] *E.g.*, by Arnold Toynbee (1852−1883). See Toynbee 1927 [1884]; 1956 [1884].

[8] It is worthy to take note that each phase of production revolution distinctly changes modes of energy production, distribution, and consumption and diffuses such new modes. It was Leslie White (1949, 1959) who pointed out to a certain evolutionary sequence in the changes of energy sources of the human societies.

[9] The possibility of the new phase of this revolution was already discussed by Volkov (1965, 1967: 391; 1968, 1976), who called it the 'second industrial revolution', though he imagined the development of this revolution in a rather one-sided (and in some respects even primitive) way, as the development of full automation without paying attention to its information technology aspects. See also Sylvester and Klotz 1983.

[10] Such a cyclical pattern accounts for a number of historical phenomena – for example, some slowdown of the production innovation rate in the last centuries BCE and the 1st millennium CE. This was a period when the most part of the creative energy was dissipated in order to enhance the military-political and sociocultural aspects of social life, as the material basis for this had already been created.

[11] Note that this date is not identical with the modern datings of the emergence of *Homo sapiens sapiens* (100,000–200,000 years ago). Though discoveries of the recent decades have pushed the date of the *Homo sapiens sapiens* formation back in time to 100–200 thousand years ago (see, *e.g.*, Stringer 1990; Bar-Yosef and Vandermeersch 1993; Pääbo 1995; Gibbons 1997; Holden 1998; Culotta 1999; Kaufman 1999; Lambert 1991; Zhdanko 1999; Klima 2003: 206; White *at al.* 2003), the landmark of 40,000–50,000 years ago still retains its major significance. This is that time, since which we can definitely speak about humans of the modern cultural type, in particular, about the presence of developed languages and 'distinctly human' culture (Bar-Yosef and Vandermeersch 1993: 94). And though there are suggestions that developed languages appeared well before 40–50 thousand years ago, these suggestions remain rather hypothetical. Most researchers suppose that the dependence on language did not appear until 40,000 years ago (see Holden 1998: 1455), whereas, as Richard Klein maintains, 'everybody would accept that 40,000 years ago language is everywhere' (see Holden 1998: 1455). Richard Klein, a paleoanthropologist at Stanford University, has offered a theory which could explain such a gap between the origin of anatomically modern *Homo sapiens* and much later emergence of language and cultural artifacts: The modern mind is the result of a rapid genetic change. He puts the date of change at around 50, 000 years ago, pointing out that the rise of cultural artifacts comes after that date, as does the spread of modern humans from Africa (see Zimmer 2003: 41 ff.). So the period 50,000–40,000 yeas ago was the time from which social forces became the main driving force of human development; from this time it appears possible to speak about real social evolution.

[12] Or using the title of Paul Mellars and Chris Stringer's book such a radical turn can be called 'The Human Revolution' (see Mellars and Stringer 1989).

[13] During the last glacial epoch, Würm III. The glacial maximum was observed about 20000–17000 BP when temperatures dropped by 5 degrees (Velichko 1989: 13–15).

[14] The point of view that, besides the 18th century industrial revolution, there was also an earlier industrial revolution (or even industrial revolutions) is widely accepted in Western science (Bernal 1965; Braudel 1973, 1982, 1985; Hill 1947; Johnson 1955, *etc.*), but within Russia it does not have many advocates (however, see Islamov and Frejdzon 1986: 84; Gurevich 1969: 68; Dmitriev 1992: 140–141).

[15] Besides one should take into account the point that precisely this generation will have the 'control packet' of votes during elections (taking into account the fertility decline that is likely to continue throughout this century), and it is not clear if this generation will be able to react adequately to the rapidly changing situation. On the acceleration of historical time and the necessity of stabilization see Grinin 1998a; see also Diakonoff 1999: 348; Kapitza 2004a, 2004b, 2006; Korotayev, Malkov, and Khaltourina 2006a, 2006b. Yet, there also exist tendencies to slowing down this development. S. Tsirel (2007) pays attention to one of them. He points out that 'ordinary' time (*i.e.* everyday, common tempos and rhythm within the limits of usual human existence) starts to hamper historical changes, because it is hard for people to break themselves of the habit of what

they got accustomed to in childhood and youth, they deliberately or unconsciously resist changes in various ways. Actually one may completely agree that this sound conservatism is able to prevent acceleration. However, will such a tendency of hampering be powerful enough? There is much doubt about it.

[16] It appears reasonable to mention here works of Chuchin-Rusov (2002) and Kapitza (2004b, 2006). Some ideas about the detection of mathematical regularities were expressed by Igor Diakonoff. In particular, he wrote the following:

> There is no doubt that the historical process shows symptoms of exponential acceleration. From the emergence of *Homo Sapiens* to the end of Phase I, no less than 30,000 years passed; Phase II lasted about 7,000 years; Phase III about 2,000, Phase IV, 1,500, Phase V, about 1,000, Phase VI, about 300 years, Phase VII, just over 100 years; the duration of Phase VIII cannot yet be ascertained. If we draw up a graph, these Phases show a curve of negative exponential development (Diakonoff 1999: 348).

However, Diakonoff did not publish the graph itself. Snooks suggests a diagram called 'The Great Steps of Human Progress' (1996: 403; 1998: 208; 2002: 53), which in some sense can be considered as a sort of historical periodization, but this is rather an illustrative scheme for teaching purposes without any explicit mathematical apparatus behind it.

[17] In general many historical processes may be represented as regular cyclical rhythms of the functioning of economical, social and other human structures. Such ideas were developed, for example, by Braudel (1977). It is especially worth pointing here at historical demographical and also economic cycles, among which the most famous are so-called Kondratiev's ones (for the references on these and other cycles see Grinin, Korotayev 2007).

[18] The absolute length of a phase (or a sum of the lengths of two or three phases) is divided by the full length of the respective production principle. For example, if the length of the hunter-gatherer production principle is 30,000 years, the length of its first phase is 10,000, the one of the second is 8,000, the duration of the third is 5,000, then the ratio of the first phase length to the total production principle length will be 33,3 %; the ratio of the sum of the first and the second phases' lengths to the total production principle length will be 60 %; and the ratio of the sum of the first, the second, and the third phases' lengths to the total production principle length will be 76,7 %.

[19] Within the calibrated scale the changes from one principle of production to another are considered as changes by an order of magnitude, whereas changes within a principle of production are regarded as changes by units within the respective order of magnitude. Such a calibration appears highly justified, as it does not appear reasonable to lay off the same value at the same scale both for the transition from one principle of production to another (for example, for the Agrarian Revolution), and for a change within one principle of production (*e.g.*, for the development of specialized intensive gathering). Indeed, for example, the former shift increased the carrying capacity of the Earth by 1–2 orders of magnitude, whereas the letter led to the increase of carrying capacity by 2–3 times at best.

[20] It appears that mathematical analysis of these internal cycles of the historical process formations (that is the recurrence of evolution pattern within each cycle) has not yet been done and is performed for the first time in the present article (see also Grinin 2006a).

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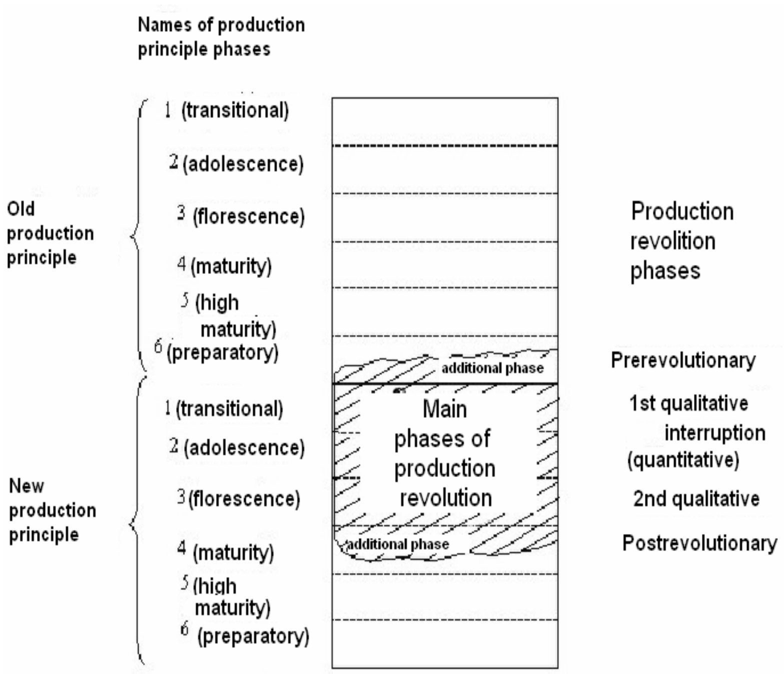


Fig. 1. Correlation between Phases of Production Principles and Phases of Production Revolutions

Explication:

/ / / / – temporal volume of production revolution

—— – borders between production principles

Table 1

Chronology of Production Principle Phases
(Figures before brackets correspond to absolute datings (BP); figures in brackets correspond to years BCE. Bold figures indicate phase lengths (in thousands of years)

Production principle	*1st phase*	*2nd phase*	*3rd phase*	*4th phase*	*5th phase*	*6th phase*	*Overall for production principle*
1. Hunter-Gatherer	40 000–30 000 (38 000–28 000 BCE) **10**	30000–22 000 (28 000–20 000 BCE) **8**	22 000 –17 000 (20 000–15 000 BCE) **5**	17000–14 000 (15 000–12 000 BCE) **3**	14 000–11 500 (12 000–9500 BCE) **2.5**	11 500–10 000 (9500–8000 BCE) **1.5**	40 000–10 000 (38 000–8000 BCE) **30**
2. Craft-Agrarian	10 000–7300 (8000–5300 BCE) **2.7**	7300–5000 (5300–3000 BCE) **2.3**	5000–3500 (3000–1500 BCE) **1.5**	3500–2200 (1500–200 BCE) **1.3**	2200–1200 (200 BCE–800 CE) **1.0**	800–1430 CE **0.6**	10 000–570 (8000 BCE–1430 CE) **9.4**
3. Industrial	1430–1600 **0.17**	1600–1730 **0.13**	1730–1830 **0.1**	1830–1890 **0.06**	1890–1929 **0.04**	1929–1955 **0.025**	1430–1955 **0.525**
4. Information-Scientific	1955–2000 (1955–1995)* **0.04–0.045**	2000–2040 (1995–2030) **0.035–0.04**	2040–2070 (2030–2055) **0.025–0.03**	2070–2090 (2055–2070) **0.015–0.02**	2090–2105 (2070–2080) **0.01–0.015**	2105–2115 (2080–2090) **0.01**	1955–2115 (2090) [forecast] **0.135–0.160**

* In this line figures in brackets indicate the shorter estimates of phases of the Information-Scientific production principle (the fourth formation). Starting from the second column of this row we give our estimates of the expected lengths of the Information-Scientific production principle phases.

Table 2

Production Principles and Their Phase Lengths (in thousands of years)

Production principle	*1st phase*	*2nd phase*	*3rd phase*	*4th phase*	*5th phase*	*6th phase*	*Overall for production principle*
1. Hunter-Gatherer	10	8	5	3	2.5	1.5	30
2. Craft-Agrarian	2.7	2.3	1.5	1.3	1.0	0.6	9.4
3. Industrial	0.17	0.13	0.1	0.06	0.04	0.025	0.525
4. Information-Scientific	0.04–0.045	0.035–0.04*	0.025–0.03	0.015–0.02	0.01–0.015	0.01	0.135–0.160

* This line indicates our estimates of the expected lengths of the Information-Scientific production principle phases.

Table 3

Ratio of Each Phase (and Phase Combination) Length to the Total Length of Respective Production Principle (%%)

Production principle	*1*	*2*	*3*	*4*	*5*	*6*	*1–2*	*3–4*	*5–6*	*1–3*	*4–6*
1. Hunter-Gatherer	33.3	26.7	16. 7	10	8.3	5	60	26.7	13.3	76.7	23.3
2. Craft-Agrarian	28.7	24. 5	16.0	13.8	10.6	6.4	53.2	29.8	17	69.1	30.9
3. Industrial	32.4	24.8	19	11.4	7.6	4.8	57.1	30.5	12.4	76.2	23.8
4. Information-Scientific	28.1 (29.6)*	25 (25.9)	18.8 (18.5)	12.5 (11.1)	9.4 (7.4)	6.3 (7.4)	53.1 (55.6)	31.3 (29.6)	15.6 (14.8)	71.9 (74.1)	28.1 (25.9)
Mean	30.6**	25.3	17.6	11.9	9	5.6	55.9	29.6	14.6	73.5	26.5

* In this line figures in brackets indicate the shorter estimates of phases of the Information-Scientific production principle (the fourth formation).

** The calculation of mean took into account only one version of the information-scientific production principle evolution (that is figures before brackets).

Table 4

Comparison of Phase Length Ratios for Each Production Principle (%%)

Production principle	*1:2*	*2:3*	*3:4*	*4:5*	*5:6*	*(1+2): (3+4)*	*(3+4): (5+6)*	*(1+2+3): (4+5+6)*
1. Hunter-Gatherer	125	160	166.7	120	166.7	225	200	328.6
2. Craft-Agrarian	117.4	153.3	115.4	130	166.7	178.6	175	224.1
3. Industrial	130.8	130	166.7	150	160	187.5	246.2	320
4. Information-Scientific	112.5 (114.3)	133.3 (140)	150 (166.7)	133.3 (150)	150 (100)	170 (187.5)	200 (200)	255.5 (285.7)
Mean*	121.4	144.2	149.7	133.3	160.9	190.3	205.3	282.1

* The calculation of mean took into account only one version of the information-scientific production principle evolution (that is figures before brackets).

Diagram 1. **Hunter-Gatherer Production Principle**

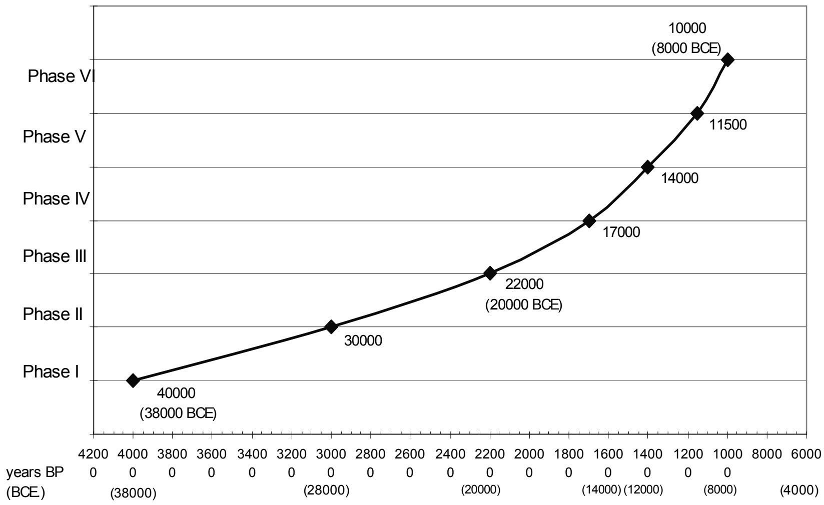


***Diagram 2*.** **Craft-Agrarian Production Principle**

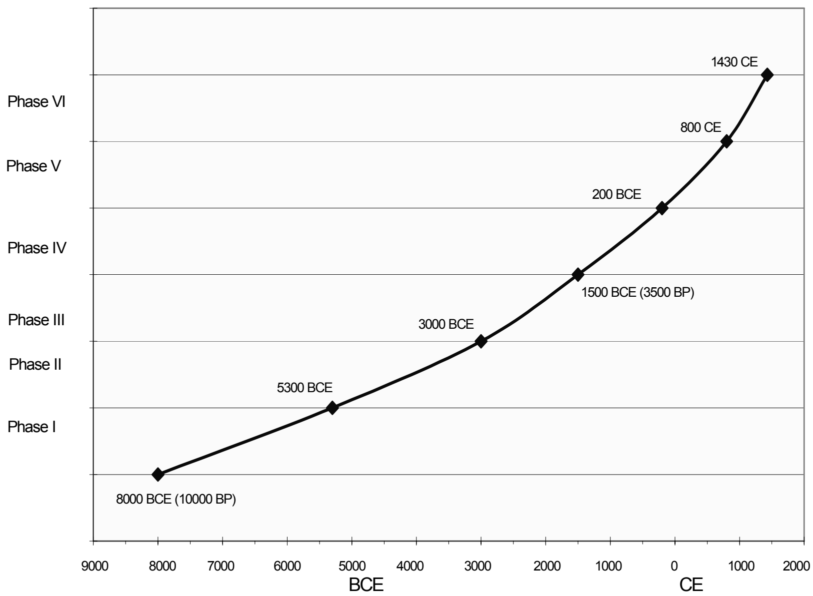


***Diagram 3*. Industrial Production Principle**

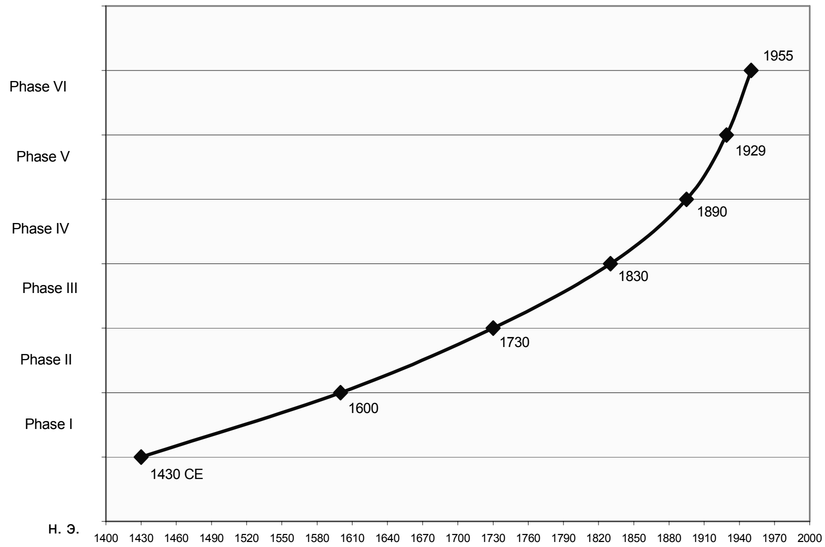
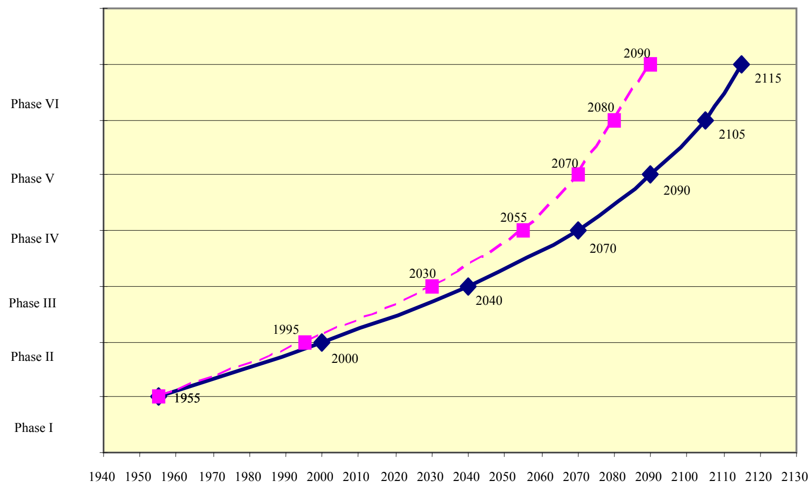


***Diagram 4*. Information-Scientific Production Principle**



Note: the broken line indictates the forecast version for the expected development of the information-scientific production principle corresponding to dates in brac**kets in** the 5th line of Table 1.

***Diagram 5.* Evolution of Historical Process in Time**

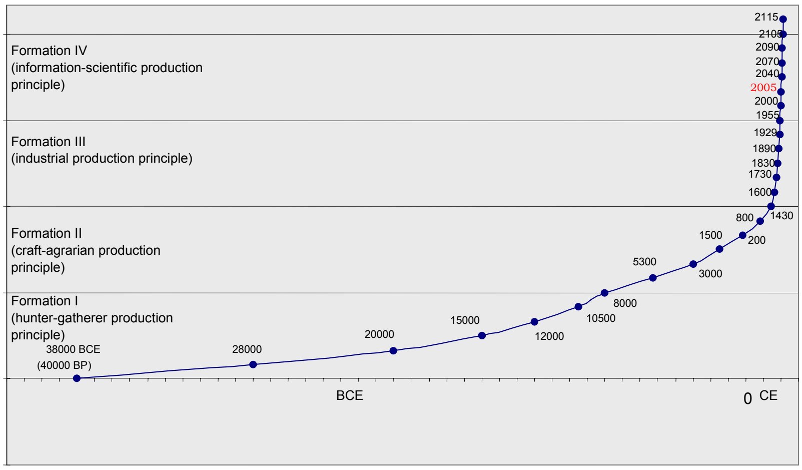


***Diagram 6.* Hyperbolic Model of Historical Process Dynamics**