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Revealing the Historical Trend of Households' Decay

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Abstract

Based on empirical facts and general context, a historical decrease of the average households' size is revealed which follows an almost linear law with a rate of approximately minus 0.02 persons per year. An attempt is made to theoretically substantiate the linear law of households' decay on the basis of the model of hyperbolic mankind growth formulated by S. Kapitza in terms of a specific unit of time and evolution of the regional populations. A hypothesis is proposed and justified that the linear households' decay forms a mankind historical time arrow similar to the arrow of world population growth. The hypothesis of two social evolution eras is proposed and justified. Within the genus-tribal era, households have almost constant sizes and are the subjects of hyperbolic growth. In the modern era, Kapitza's regional populations have almost constant sizes and are the subjects of hyperbolic growth, while the households begin their historical decay up to the size equal to 1. The total time required for the implementation of both eras is significantly less than previous estimates and is about 20,000 years. In the modern era, informational exchange stimulates the growth of human capital and consistently frees people from the need for collective labor for survival, and for this reason it is identified as a possible cause of the households' decay.

Keywords: households' decay, households' evolution, households' size, family community, labor collective, demographic transition, arrow of historical time.

1. Introduction

Households and families have many definitions. In the context of our research, these are traditional associations of men and women for living together, working, and raising children. Households and families have different asymptotes when decreasing size: unit for the household and uncertainty for the family. Indeed, a family of two should have a size of 2, and a 'family' of one should have a size of 0. For this reason, the household category, which is more natural for the smallest sizes, is used in modern demography. The categories of family and household lose their usual modern interpretation when they reach extremely large sizes, which was the case in the distant past. Very large 'household' could use many houses, and very large 'family' could consist of many nuclear or extended families and could include not only relatives, but also servants, slaves, and captives. Joint labor, joint military operations, and joint food have been combining a large household into a 'social unit'. The terms "compound household", "corporate household",

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"community of individual households", "multifamily corporate group", "cooperative group", "multiple-family household", "family community", etc., are used in the scientific literature to refer to very large households of the past. For almost all historical time, the household has brought people together for survival through joint agricultural production; for this reason, it is the surviving rural households that are the focus of our attention.

It is known that the households of every country in the world where demographic statistics take place reduce their size, refer to the current publications (UN, 2019) where the overall decline in fertility happens to be a clear (but isn't direct) indicator of households degradation. The growth of average sizes of national households and even their stabilization over historically significant time intervals, e.g. 50 years and more, were not observed. As an example, Figure 1 shows a graph of the historical decline in average size of US households from 1790 to 2020.

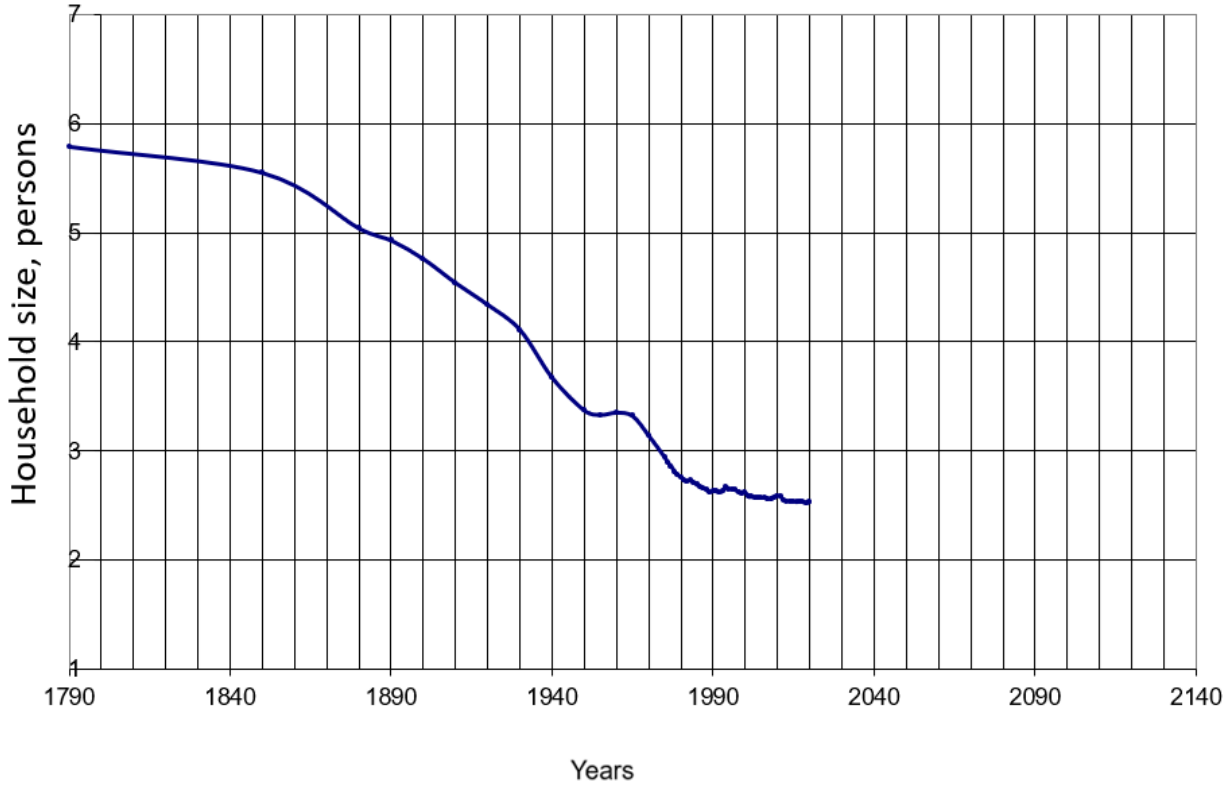

Fig. 1. US household sizes from 1790 to 2020 according to the US Census Bureau (Statista, 2021; Fry, 2019; Infoplease, 2021)

The fact of the historical decline in average size of households or families is recognized by demographers and even has an explanation through the idea of increasing the cost of giving birth and raising children of increasing quality, we refer to the G. Becker model, built on the production function (Becker, 1993). This model assumes that the production of children is economically profitable, since the grown child will pay for the family costs in the future. The historical trend towards a decrease in family size is explained by the dubious improvement in the quality of children's education due to a decrease in their number. The Becker model does not answer an even larger question about the reasons for the formation of human labor collectives, leaving in a theoretical fog the oldest times in the history of mankind.

The speed of relative decrease of households' size is so great now that the phenomenon of their disintegration has become noticeable during the individual's life. Meanwhile, the birth and initial (most important) upbringing of children are possible primarily within the family. Will society preserve itself if households degenerate and this opens the door to mass irresponsibility and laziness of the last generations of people? There are reasons to assume that the average households' size is one of the parameters of the hierarchy of national power (Loshchinin, Privalov, 2016). Will the government lose its force in the conditions of the upcoming depopulation, when its force will be needed as never before? We emphasize that the collapse of households in our time is accompanied by an increase in the traditional ills of humanity: "systematic forms of injustice, discrimination,

opposition, poverty, socio-economic inequalities, and lack of equity, all of which have too often escaped discourse". We quote an article published by S. Prescott about the new era of planetary challenges (Prescott, 2021). The main purpose of our cross-sectional study is to analyze the trends, reveal the law and rate, and offer models that explain the historical decline of average households' size, as well as draw the attention of specialists to the dangerous consequences of global households' decay.

2. Results and discussion

2.1. Households' decay law

From the Figure 1, it can be seen that the decay (in other words the breakdown, disintegration, fission) of households slowed down before 1890 and after 1990. Apparently, the reason for the slowdown was the mass immigration to United States, which was particularly intense at that time (Wikipedia, Immigration to US). Strictly speaking, we have no legal reason to extend the graph to the left in the past before the date of United States founding in the late 18th century, and before the intensive formation of European settlements in North America since the mid-17th century in a demographic sense. However, the far-left extrapolation makes general historical sense, since the first European colonists carried with them the ways of family life of the Old World with its thousand-year demographic history.

If on the Figure 1 we connect the points (1790; 5.79) and (2020; 2.63) by a straight line with a slope (2.63 – 5.79)/230 = – 0.014 people/year and move this line to the right in the future, then we can expect that US households will reach an extreme value of 1 by 2139. It can be assumed that this extreme state may await all developed countries and even humanity as a whole in the foreseeable future; this is our first conclusion. If we plot the same trend to the left in the past, we can assume that 3020 years ago (1000 years BC) families had an average size of 44 people, this is the size of a small ancient family community. Thus, the modern demographic trends are quite capable to connect the family or the household of the end of 21st century with the genus-tribal structure of ancient societies and to do it linearly with time; this is our second conclusion.

In modern sources, we can hardly find only rare, incomplete, and unsystematic information about the size of households or family communities in the retrospect of thousands or even more than several thousand years. Historical demographers P. Laslett and R. Wall combined the research of colleagues in the collection of works "Household and family in past time" (Laslett, Wall, 1972), from which we can get some numerical information that is important as reference points. For example, in Chapter 14, E. Hammel mentioned the Serbian zadruga-families (large families, communities, fraternities), uniting up to a hundred relatives for the primitive survival in the past (Hammel, 1972). In Chapter 16, J. Halpern reported that Serbian households had more than 6 members in 1863 (Halpern, 1972). In Chapter 18, A. Hayami and N. Uchida reported that Japanese families had an average size of 20-30 people in the 8th and 9th centuries (Hayami, Uchida, 1972).

The last estimates suggest that:

1) The further into the past, the larger the family,

2) In recent centuries, the process of households' decay has been proceeding at a similar rate in all countries involved in global population migration, and

3) In the future, households' decay will end almost simultaneously throughout the world.

Let suppose that the average households' size $n(T)$ in Europe in 800 was 25 people, as in Japan, and in 1850 it was 6 people, as in the United States and the Balkans. It means that the average rate of decay $\dot{n}(T)$ is about 0.02 people / year, or 1 person per 50 years, or about 1 person per natural unit of 'Kapitza time' (τ = 45 years), which appears in his equations of hyperbolic growth of the Earth's population (Kapitza, 2004: 79, 81, 86, 250-255). The social meaning of the parameter τ according to Kapitza's idea is the average life expectancy of people or half of the time of demographic transition. The time parameter equal to 50 years was also proposed by A. Byalko to explain the time of the fertility response to climate variations and was interpreted by him as the average life expectancy (Byalko, 2020). The same (about 0.02 people/year) was the rate of households' decay in the United States during the period of small immigration from 1885 to 1935. It is no coincidence that we mentioned the book by S. Kapitza, our study continues a previously

initiated cycle of work in the wake of his theoretical demography (Ojovan, Loshchinin, 2015; Privalov et al., 2016).

If after 2020 the decay of US households will occur at a unit of rate, then the intersection of the trend of size evolution with the horizontal axis will happen within (2.63 – 1) / 0.02 = 82 years, i.e. in 2102. And similarly, 1000 years BC, at the unit of rate and linear decay, family communities could have the size of 63 people, which is even closer to the image of a large family community that takes place in the books of 19th-century evolutionists, primarily L. Morgan (Morgan, 1907) and M. Kovalevsky (Kovalevsky, 1939; 1890). The decay of households is really similar to a linear one.

If the United States, as a result of economic competition, cedes world leadership to China and India, then immigration may change to emigration, the collapse will accelerate, and households in the United States will reach a critically small average size in the 21st century. Figure 2 repeats the graph from Figure 1, extrapolated by a linear function $y = -0.0177x + 38.105$ ($R^2 = 0.9443$) and show the third variant of possible scenario, the most probable mathematically.

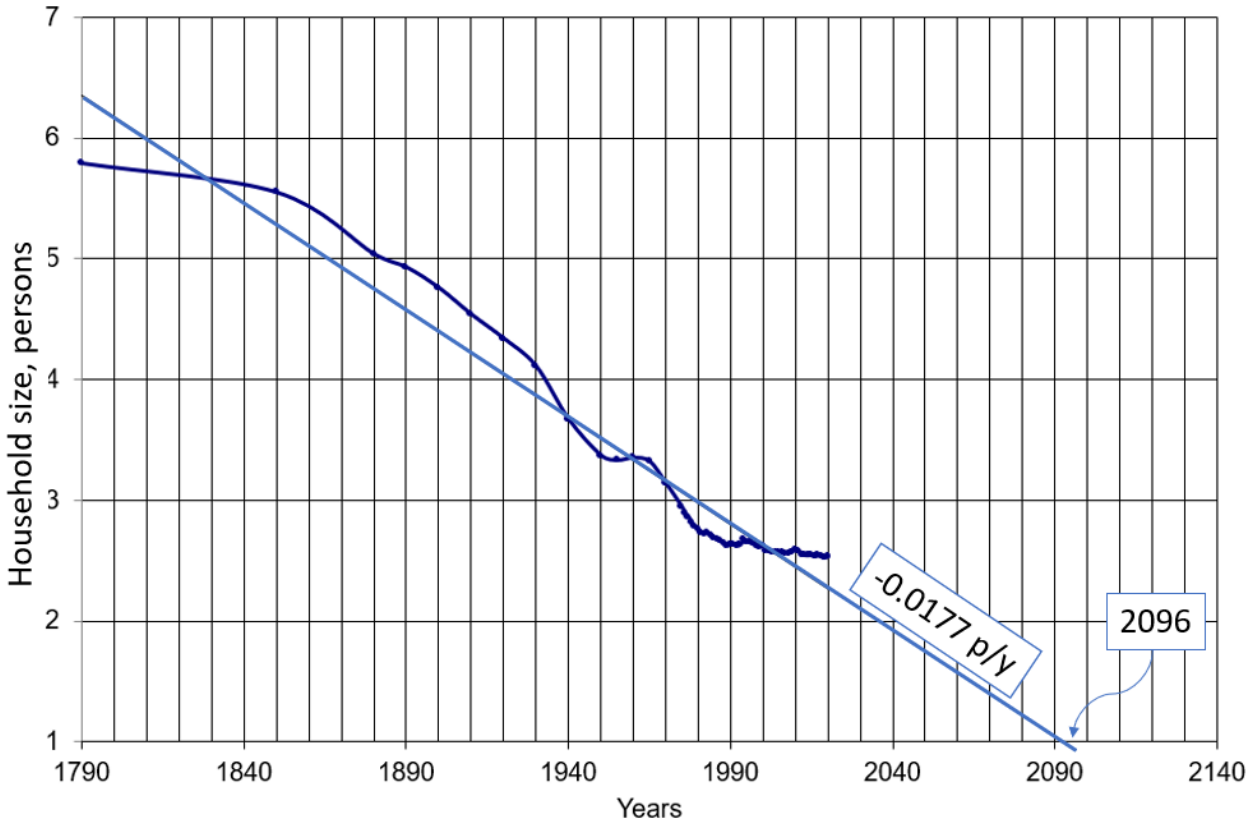

Fig. 2. On the example of the US demographical statistics, the built-in Excel program extrapolates the graph in Figure 1 linearly up to the intersection with axis X, which gives 2096 as the year of extremely small households

What is the maximum size that ancient households could have? This is what we find in Morgan's book "Ancient Society" (Morgan, 1907: 399, with the reference on Herrera). "As we descend the scale in the direction of the punaluan and consanguine families, the household group becomes larger, with more persons crowed together in the same apartment. The coast tribes in Venezuela, among whom the family seems to have been punaluan, are represented by the discovers as living in bell-shaped houses, each containing a hundred and sixty persons". Somewhat further on, Morgan repeats Herrera's report (Morgan, 1907: 431).

In Chapter 8 of the book "Mathematical models for the growth of human populations", J. Pollard cites the opinion of famous anthropologist F. Galton, published in 1874, about the demography of aristocratic families. It is characteristic that against the background of the rapid growth of the world's population, Galton used such categories as "decay of families", "element of degradation", "diminished fertility" (Pollard, 1973: 97). In our historical time, these categories are already applicable to the majority of society. How do the growing global population,

the disappearing fertility of women and the decreasing household sizes combine? We should understand this paradox.

2.2. The household as a labor community and a social unit

There is an even more general question: why did ancient people live together? It would seem that this question has an obvious answer: people united for the sake of defense and attack, as well as for the sake of joint production and consumption the boons for survival. A household is a labor community, it is a collective (team) of people who live and work together. Nevertheless, the idea of a family community (or household) as a labor community still does not win in sociology, we refer to modern popular online sources where the labor purpose of a family or household is not even discussed (Wikipedia, Family; Household). L. Morgan, like his colleagues-evolutionists, ignored the labor communities of our distant ancestors. In his book, ancient society is presented as a system of sexual and kinship relations, but not the labor ones. Morgan went even further, because he did not recognize a special mission of the family (or household) at all.

Arguing with most of his colleagues (G. Grote, B.-G. Niebuhr, Thirlwall, H. Maine, T. Mommsen, "and many others"), who considered the family community to be the basis of ancient social structures, Morgan often repeated his credo: "The gens ... does not recognize the existence of the family of any form as a constituent of itself." And else: "The gens was homogeneous and to a great extent permanent in duration, and as such, the natural basis of a social system." (Morgan, 1907: 233). Meanwhile, the number of members of Indian genus in the United States, according to Morgan's estimate, was from 100 to 1000 (Morgan, 1907: 87), and then Morgan expands this interval down to 50 (Morgan, 1907: 161, 173, 175) and up to 1500 (Morgan, 1907: 166) and even to 1750 people (Morgan, 1907: 168). It is impossible to imagine that communities of 300-1750 people in labor and in battle were managed as a whole, without being divided into the small collectives. On the contrary, the smallest indivisible and 'incompressible' part of the genus with a size of 50-150 people looks like the family community we are looking for.

L. Morgan's research is remarkable in that it is broader than the author's personal preferences and tendentiousness. In particular, in his book we find a very informative fragment from the letter of his colleague A. Wright about the Indians family community in Seneca's "old long-houses" (Morgan, 1907: 464): "Usually, the female portion ruled the house, and were doubtless clannish enough about it. The stores were in common; but woe to the luckless husband or lover who was too shiftless to do his share of the providing. No matter how many children, or what-ever goods he might have in the house, he might be ordered to pick up his blanket and budge; and after such orders it would not be healthful for him to attempt to disobey. The house would be too hot for him; and unless saved by the intercession of some aunt or grandmother, he must retreat to his own clan; or, as was often done, go and start a new matrimonial alliance in some other. The women were the great power among the clans, as everywhere else. They did not hesitate, when occasion required, 'to knock off the horns', as it was technically called, from the head of a chief, and send him back to the ranks of the warriors. The original nomination of the chiefs also always rested with them".

In fact, A. Wright described a labor family collective in the Seneca tribe with a matriarchal form of government and with strict discipline, aimed at ensuring the boons and conditions for survival in joint work and military actions. Food supplies (the most important property of the family community) are particularly noted. The division of functions is interesting: family life is led by women, and military affairs are entrusted to men-'warriors'. The letter is dated 1873, but sets out, of course, earlier observations. In the Old World, such family communities operated earlier than 1000 years BC. The Neolithic era, which started in Europe 7 thousand years BC (Wikipedia, History of Europe), was already the time of action of family communities, i.e. the large labor and military collectives of our ancestors.

The sociologist and evolutionist M. Kovalevsky analyzed the history of law and traditions of European, Caucasian, and Asian peoples and concluded that the process of social development is represented by three different phases of the matriarchal, patriarchal, and individual families. We refer to the course of lectures by Kovalevsky, reprinted in 1939 in the USSR, which he delivered at Stockholm University in 1890 (Kovalevsky, 1939: 15). The original course was published in French (Kovalevsky, 1890). Despite the recognition of genus-tribal structure, it is the family community that is considered as a social unit in Kovalevsky's research. The evolution of the family was presented by him as a process of disintegration (breakdown, decay) of large

family communities, and he found specific signs of their disintegration in all nations of the world. Unlike L. Morgan, who very often used the term "progress", Kovalevsky no less often used the term "dissolution (Fr.)", but the historical reduction in the size of family communities was not recorded by him. Kovalevsky, like L. Morgan and F. Engels, was primarily attracted to the evolution of sexual, legal, and religious relations. Therefore, in the course of Kovalevsky's lectures, we cannot find numerical data linking the historical time and the middle or typical sizes of the labor communities.

The works of modern historical demographers has significantly advanced the understanding of the evolution of households, despite the consistently poor information about their size. The collection of articles, published in 2013 under the editorship of M. Müller, presents the results of archaeological excavations of small ancient cities near the Mediterranean Sea (Müller, 2013a). In the Chapter 15, Müller writes about the wealth of households in Balat (ancient Egypt, 600-800 AD): "an average number of ten to twenty-five people could be provisioned by the volume of stored grain on the different estates over time." She writes also about the size of another rich household "At least nineteen members of the household comprise the extended family… In addition, the household includes at least ten dependents" (Müller, 2013b: 359).

In the Chapter 9, J.-A. Dickmann describes in detail the architecture of a huge rich ancient (79 AD) house at Pompeii with an area of about 1000 m² and with a number of rooms and spaces of about 50 (Dickmann, 2013: 211-228). Dickmann estimates the size of the staff (the number of servants and slaves) as close to 20, apparently excluding their children who lived there (Dickmann, 2013: 225). The total number of inhabitants of the house Dickmann also does not count, but it is unlikely that it was less than 50. These numbers are important to us as indicators of the scale of ancient family communities. The book edited by M. Müller is filled with uniquely rich information about the architecture of ancient buildings and the domestic life of their inhabitants (Müller, 2013a). "The language of houses" would be a good reason to study the average size of households (and mainly rural ones), but the attention of specialists was not aimed at this subject.

The collection of works by archaeologists on "rural household production" based on the results of excavations on the American continent, published under the editorship of J. Douglass and N. Gonlin, develops the concept of the household as a producer of good (Douglass, Gonlin, 2012a). In the Chapter 1 named "The household as analytical unit", they write: "First and foremost, households are responsible for providing household members with sustenance (i.e., subsistence) for the continued reproduction and success of the group" (Douglass, Gonlin, 2012b: 10 with reference on R. Netting, R. Wilk, and E. Arnould 1984; Wilk and Netting 1984). The epithets awarded to households are characteristic: "the most fundamental unit of society" (p. 2 with reference on W. Ashmore and Wilk 1988; Netting, Wilk, and Arnould 1984), "the most common social component of subsistence", "the smallest and most abundant activity group" and also "the demographic unit" (pp. 2-3 with reference on Wilk and W. Rathje 1982).

The archaeologists who estimated households' size reports data supporting generally the previously mentioned pattern: the further back in time, the larger the size of rural households. For example, in the Chapter 4 "Iroquoian households", D. Snow investigates ancient rural settlements (New York State, 15-16 centuries AD) and marks the next: "Each Iroquois village comprised a few to few dozen of the real longhouses, tended to 6 m wide and up to 100 m in length" (Snow, 2012: 119-120). Snow singled out a separate section for the topic "The longhouse social unit" where he writes: "A senior woman presided over the clan segment (matrilineage) that occupied each longhouse along with in-marrying male spokes. Nuclear families tended to average five people… Thus each compartment, typically containing two cooperating nuclear families, had an average population of ten people. One can reasonably compute the population of a longhouse by multiplying the number of hearths (fires) by ten… Longhouses built in the fifteenth century often had three to five fires, implying population of thirty to fifty people" (Snow, 2012: 122).

In the Chapter 9 "Understanding households on their own terms", H. Henderson mentions P. Carrasco, who analyzes colonial census of 1540 from Molotla and "documents compound households… which featured two to four houses around a central patio, which had on average 5.2 married couples and 23.2 people. The total population range for these corporate households was twelve to thirty-five people" Henderson, 2012: 279). Similarly, N. Farriss was named who estimates that prior to the Spanish conquest, larger households in the Maya lowlands contained twenty to thirty adults and children. Henderson generalizes: "At K'axob, the clearest category of

large households was the large corporate residence, which included two to six structures jointed around a paved plaster patio" (Henderson, 2012: 279).

The idea of the household as a "social unit" was repeatedly used by the authors of discussed collection of works and was emphasized by references to the positions of many colleagues. In the section "Households as primary producers", J. Douglass and N. Gonlin mention the names of specialists who develop the same idea of collective production as the main mission of households: R. Netting, R. Wilk, E. Arnould, K. Hirth, D. Arnold, P. Arnold, M. Graves, A. Pyburn, N. Dunning, T. Beach, S. Fedick, P. Harrison, B. Turner, V. Scarborough, H. Brookfield, I. Farrington, R. Ciolek-Torrello, H. Henderson, L. Neff, T. Killion, W. Doolittle, S. and P. Fish, C. Downum, P. Sheets, C. Szuter, C. Robin, D. Wiewall, V. Gonzalez Fernandes, C. Hastorf. (Douglass, Gonlin, 2012a: 10-11). It is clear how broad this scientific direction turned out to be. We are very impressed with the general approach of J. Douglass and N. Gonlin, as it helps to stop the ignoring central role and labor nature of households that has happened in the scientific literature since the first evolutionists.

2.3. Non-linearity of the household as a producer of good

In Lecture 4, Kovalevsky notes the force-increase provided by a solid collective to each of its participants: "a lonely person is unable to resist on his own in the struggle for existence: he needs help and support, and thanks to the collective, his efforts increase tenfold" and "the impotence, both intellectual and physical, forces primitive man to engage in production only together with others" (Kovalevsky, 1939: 57-58).

In the Chapter 7 "Pots and agriculture: Anasazi rural household production, Long House Valley, Northern Arizona", J. Douglass and R. Heckman report the results of investigations of ancient (1000-1150 AD) family pottery production in named rural areas. About the cooperation of individual nuclear families within a common household, they write: "several cooperative families living together in an architectural suite may form a household" and specifically note "a high degree of cooperative behavior" (Douglass, Heckman, 2012: 191-192).

Previously mentioned, H. Henderson compares large and small ancient households in settlements near K'axob, Beliz (lowland Maya, ninth century BC – ninth century AD), and writes: "Larger households were better able to pool labor and resources to produce an even more diverse array of staple foods. Smaller households, by comparison, focused more of their labor and resources on maize agriculture. Larger households were wealthier, with more elaborate architecture, and featured more sequential occupations, more then double the number of smaller households" (Henderson, 2012: 270). A similar opinion about the advantages of large ancient (last centuries BC) households is expressed by R. Ciolek-Torrello in the Chapter 8 "Hohokam Household Organization, Sedentism, and Irrigation in the Sonoran Desert, Arizona". He writes: "Larger households may have been a response to the need to divide labor among various simultaneous tasks because resources or field systems were dispersed or because of the greater demands for pooled labor to construct and maintain intensive irrigation systems" (Ciolek-Torrello, 2012: 224).

Henderson emphasizes an important methodological aspect: the concept of the household as a producer of good changes the approach to the interpretation of archaeological data. He's writing: "Archeologists cannot directly observe the cooperative efforts of people who coordinate different activities, and the lack of this information creates an analytic dilemma for archeologists who want to reconstruct and analyze households in the past. Unless archeologists begin household studies by questioning how households internally managed life-supporting activities, it is unlikely that we can deduce household boundaries and think about how shared activities would have brought together household members, created friction, or ever pulled them apart" (Henderson, 2012: 271).

The monotonous relationship between the size of the household and the well-being of its members has been repeatedly noted by the authors of discussed collection of works. For example, in the Chapter 1 with references to coauthors (C. Beaule, H. Henderson, V. Gonzalez Fernández, V. McCormack, D. Wiewall) and colleagues (B. Hayden, A. Canon, R. Netting, R. Wilk, W. Rathje, C. Beaule, J. Hendon, P. McAnany), Douglass and Gonlin summarize: "Wealthier households generally tend to be larger (i.e., more people) then less fortunate ones… In agrarian societies household size may be determined in part by the ability of households to produce surplus and attract and keep household members" (Douglass, Gonlin, 2012b: 13). From the analyses of bone remains in the burials, Henderson concluded that "adult diets in corporate households were more heterogenic than those in other-side households" (Henderson, 2012: 285). He goes on to make an

even stronger claim in favor of large households: "The prosperity of larger households, beginning in the fourth century BC can be understood, in part, as a function of their ability to manage larger labor pools and coordinate a wider variety of productive activities and resources" (Henderson, 2012: 289).

A great merit of participants of the project, headed by Douglass and Gonlin, is the empirical discovery of the phenomenon of nonlinearity of solid labor collective. Indeed, if the labor of the collective's members was as productive as the simple sum of the work of all members, then personal benefits would not depend on the size of the collective, but in reality benefits grow as the size increases. The increased efficiency of a solid collective makes it possible to understand the reason for its special mission to be a social unit: surviving people unite in households, because it is profitable, because their personal force increases within a collective. However, it is still not clear why the households' sizes are historically decreasing.

2.4. The household and the regional population as the main players of social evolution

It is not the genus or the tribe, but the family community that we regard as the primary labor collective, the forerunners of which was the primitive herd or pack, and the modern successor of which is the useless childless vanishing family. The ability of people to purposefully work together increases the personal productivity, which in turn is the result of personal knowledge and experience. It is the phenomenon of personal reinforcement, but not sexual feelings or even kinship, that we consider the reason for the association of people. A solid collective is many times more productive than an equal number of independent people both in work and in battle.

The capacity (power, force) of the solid labor collective depends non-linearly (quadratic, in our model) on the number of its participants (Privalov et al., 2016). Each member of a solid collective, as it were, multiplies his human capital (i.e. his ability to produce the boons for survival) as many times as many people are united in a collective. There is no doubt that the family community (household) was the main survival tool of our ancestors, much more effective than the spear, bow, and axe. The model developed by us not only assumes a quadratic effect for solid collective, but also a decreasing efficiency in cases of uncoordinated labor. Our model allows us to propose hypotheses about the historical evolution of joint labor.

The other reason for our interest in history of the structure of ancient societies was the paradoxes in the first serious attempt to build a theoretical demography, undertaken by S. Kapitza (Kapitza, 2004). Among the pioneers of modeling the mankind growth, he called "probably first McCormic and then von Foerster, von Horner and J. Shklovsky". We think that the great advantage of Kapitza modeling is his discovery of a specific time of 45 years and specific communities with size near 62 thousand people, which he called "self-sufficient populations"; here they are called 'Kapitza's populations' or 'regional populations'. Kapitza even rewritten the Foerster's equation of hyperbolic growth (Foerster et al., 1960), replacing the total number of people with the number of regional populations (Kapitza, 2004: 255-258). Thus, it was regional populations, and not people, that Kapitza considered as the subjects of hyperbolic mankind growth. According to Kapitza, the world's population grows not by units of men or women, but by the new 'spots' of regional populations. Kapitza explained the phenomenon by means of "collective binary interaction in generation", and it is the regional populations that are the participants in this interaction. Nevertheless, the size of the regional population (62 thousand people), established by him, is comparable to the size of the entire mankind at the initial stage of evolution: Kapitza reported that the total number of people in herds of homo sapience was about 100 thousand; he referred to the opinions and publications of colleagues J. Coppens, J. Cohen and E. Deevey (Kapitza, 2004: 90). The size of regional populations is natural for the end of demographic growth, but excessive for its beginning, and this is one of the paradoxes of Kapitza's theoretical demography (Ojovan, Loshchinin, 2015), which we intend to overcome by searching for a small-sized participants in the beginning of demographic growth. We believe that a family community (household) can be such a small participant.

Joint labor and military actions of closely related family communities (households) can be considered as reliably established, we refer to the evidence of historians and archaeologists. For example, Kovalevsky writes the following. "In Australia, kangaroo hunting is carried out by the big detachments consisting of several tens or even hundreds of natives. The same thing happens when chasing a deer in the northern countries. Several united families are engaged in catching

whales and large marine fish, each of which brings its own share of equipments and food" (Kovalevsky, 1939: 57, Lecture 4). Family communities (households) were participants in positive pair interactions of exactly the same type that later took place for Kapitza's regional populations. The result of positive pair interactions of households is the generation by them of new households and, on this basis, the generation of hierarchical structures: genus as associations of households, then tribes as associations of genera, then regional populations as associations of tribes. The last is our guess, since the size of confederations (associations) of tribes mentioned by Morgan is close to the size of Kapitza's populations, we refer to Morgan's estimate of maximal number of well-studied Iroquois confederation at the level of 20,000 'souls' (Morgan, 1907: 125, Chapter V).

Note that in other Kapitza's publications the estimates of time and community characteristics were broader: $\tau \approx 42 \div 45$ years, $\sqrt{N_0} \approx 60 \div 67$ thousand, $\tau N_0 \approx 163 \div 200$ billion people multiplied by year. The content of the last two parameters will be discussed later. On the example of the numbers provided by Morgan and his followers, as well as on the example of numerical values in Kapitza's formulas and in our estimations discussed here, we want to point out their semi-quantitative nature. They are important rather as indicators of the order of magnitude. Bearing in mind the infancy of social theory and specifically of historical demography, we ask readers for friendly indulgence in such assessments. Some inconstancy of demographic parameters in the publications of different authors and even in the publications of the same author is as excusable as historical clarifications of the main constants in natural science, the original estimates of which differed from the modern ones by several times, and the modern ones can contain up to a ten or even more significant figures.

Paradoxically, the concept of regional population that Kapitza proposed is left by him without an attempt at empirical confirmation. Apparently, he was too carried away by the principle of "demographic imperative", according to which the growth of Earth's population throughout the human history depended only on the current size of Earth's population and was in no way connected with any other factors, while the concept of regional population broke this very principle. We have made a search for Kapitza's populations with an estimated area of about 1.1 ÷ 1.6 thousand km² (radius of equal-area circle of 18.7 ÷ 22.6 km) in the settlement statistics of Ukraine, Russia, Germany, and Poland and consider it be successful (Ojovan, Loshchinin, 2015; Privalov et al., 2020). The starting point of our search was the parameters from the Kapitza equations, but the results we obtained were easily interpreted in spirit of logistic ideas of C. Marchetti (Marchetti, 1994) and the archaeologists mentioned above. For example, J. Douglass and N. Gonlin with reference to colleagues (T. Killion, 1992; R. Wilk, 1983) report: "A number of ethnographic studies have shown that many outfields are within a 45-minute walk from residence" (Douglass, Gonlin, 2012b: 11), etc. The sizes of rural settlements are objective.

We suppose that the area of the regional population should allow its notification and mobilization during daylight hours. Apparently, the 'imprint' of ancient regional populations is the modern discretization of European states into areas with the mentioned sizes. The physical and administrative maps of the Federal Republic of Germany are shown in Figure 3 as an example. The areas of modern districts (kreise) of the FRG correspond to the estimated areas of Kapitza's populations.

The phenomenon of individual force (power, capacity) amplification in the case of correlated pair interaction is undoubtedly universal. It operates within households, it operates within tribes and within their unions, i.e. between regional populations. As in the case of households, the result of positive pair interactions of regional populations is an increase in the force of each through a nonlinear effect. The increased social and economic force ensures the generation of new regional populations (for example, new principalities and counties) and on this basis the generation of hierarchical structures: various kinds of associations and unions up to the creation of states and empires. Considering family communities and regional populations as the main natural actors of demographic growth, we get the opportunity to perform theoretical and historical descriptions of evolution in common natural categories. It should be noted that Morgan considered the genus, tribe and association of tribes to be natural (objective) entities and repeatedly emphasized this (Morgan, 1907: Chapters 4 and 5).

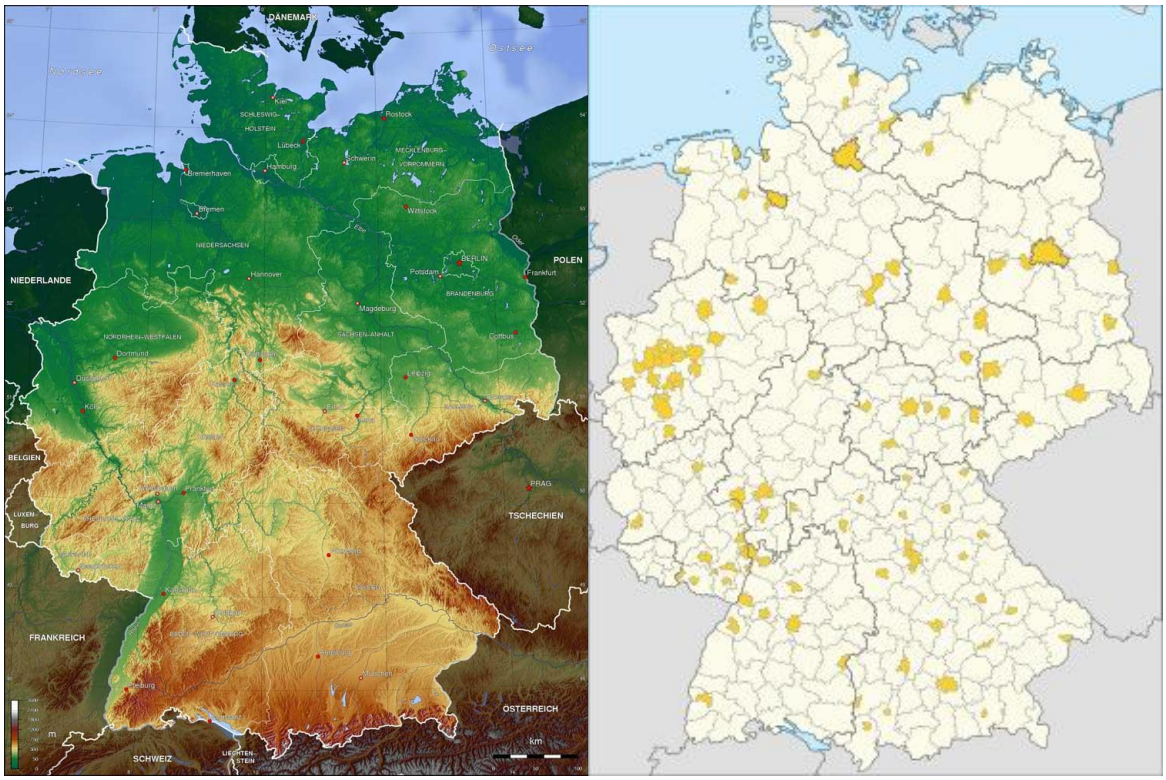

Fig. 3. Physical and administrative maps of the Federal Republic of Germany (Wikipedia, Germany; States of Germany). The average area of districts is 1,100 km² (radius = 19.1 km). The red dots on the left map and the yellow spots on the right map are the large cities. The area of district depends on the type of landscape: the areas are smaller in mountains and larger on plains in accordance with idea of notification time.

The household is a minimal structural unit with a reproducible size; it accompanies humanity throughout its social evolution, but only the discovery of nonlinearity allows us to be convinced of its fundamental role. The regional population predicted by Kapitza is the maximal community with a reproducible size; it is still waiting for its recognition, but the beginning of its study gives a hope: Kapitza's population is real and observable, and its special properties indicate a possible fundamental nature. Extending Kapitza's idea, it can be assumed that at first households, and then regional populations were carriers of social interaction that generates global population growth. Next, we will try to use the understanding we have achieved to model social evolution.

2.5. The hypothesis of two eras and two mechanisms of household evolution

Looking back at ethnographers, we are forced to distinguish between the two major eras in evolution of the household as a survival tool, they are the genus-tribal era and the modern one.

The nomadic herds of our distant ancestors could get acquainted with the vast expanses comparable with the continents. But there came a time when they found fertile places for a settled life. Here, for certainty, we tend to call them 'paradise places', despite the need for intensive collective work to receive their modest gifts. Since then, population growth has inevitably become regional, and the vast Earth in the eyes of our ancestors has been reduced to the area of a specific fertile territory, beyond which there is no any space. In thousand 'paradises places' where primitive family communities took root, the growth of the Earth's population occurred in parallel as a formal sum of the evolutions of family communities, as we assume.

Note the important: the nomadic herds are limited in size both from the bottom and from the top. In the case of military conflict and hunting, too small herds of our ancestors were weak, but too large ones were unmanageable and had much bigger feeding problems. The sizes of primitive herds and the first family communities should be recognized as objective.

For the first time since the appearance of the human species, settled survival has provided a way to increase the total number of people on Earth, because it allows to circumvent the

restriction of the maximum size of human communities and humanity as a whole as a kind of animals (about 100 thousand individuals in total as we mentioned). The upper size constraints actually appear too, but they are characterized by the much larger numbers: first it is the size of Kapitza's regional population (about several tens thousand people in every 'paradise place'), and then it is the maximal possible surviving population of the Earth (more than 4 billion people according to equations of hyperbolic growth). Settled survival defeated nomadic one not because it was easier, but because it made it possible to increase the total population and its collective force. The nomadic search for the meager gifts of nature was replaced by the settled production of boons, as we can assume.

With the development of 'paradise place' and growth of the number of family communities, the genera and tribes are formed, and then the tribal associations (regional populations) appear, where a supreme power is concentrated. It is obvious that the formation of a multi-level hierarchy of management will change the organization of military operations, and for this reason, during a genus-tribal era, the military mission is consistently transferred from households to the leaders of regional populations. Since the military mission forces the household to maintain the maximal possible size, then transferring it to the regional population removes the restriction on the size of households from below. Thus, at the end of genus-tribal era, households are able to reduce their sizes when necessary.

The number of inhabitants in the formed regional population is about ten thousand, and in the future it can reach the predicted 60 ÷ 67 thousand people (Kapitza, 2004; Ojovan, Loshchinin, 2015; Privalov et al., 2020). In the center of the regional population, as we assume, an urban-type settlement appears which is the future capital or megacity, but most often it is the future sparsely populated center of peripheral rural region.

In the modern era, the regional populations, rather than family communities, enter into a binary interaction, exchange the boons for survival and compete with each other for the possession of the new lands. Competition for land and intensive trade encourage the emergence of new populations on the new less productive places.

We should mention the most famous regional populations of antiquity; Attica with Athens in the center and Laconia with Sparta in the center are the first among them. Under Solon (600 BC), the number of registered inhabitants of Attica was about 60,000 (Morgan, 1907: 363). The area of ancient Attica was about 2,650 km² (Latyshev, 2018: 125), the radius of the equal-area circle was 29 km, which is slightly larger than the mentioned estimates of Kapitza's populations. The barren mountains made up a noticeable part (hardly less than a quarter) of Attica; the population occupied valleys connected by wide lowlands. Without taking into account the mountains in Attica, the radius of equal-area circle would be close to the radius, calculated for steppe regions of Ukraine, similar in climate (Ojovan, Loshchinin, 2015; Privalov et al., 2020). The area of ancient Laconia was larger, about 3,636 km² (Wikipedia, Laconia), but the mountains occupied about half of its territory. The population of Laconia during the Peloponnesian War (431-404 BC) was 40 ÷ 50 thousand people according to non-academic source (Athens vs. Sparta); in the academic literature there are cautious and somewhat large estimates of up to 200 thousand people (Figueira, 2003 with references to K. Beloch, 1886, and modern researchers).

We have mentioned that the personal survival requires significantly more effective human capital K_S, than the real capabilities, knowledge and skills K_i, that ancient people had: $K_S >> K_i$. The problem is solved through the collective work in a solid family community with the size n, namely

$$nK_i = K_S, \tag{1}$$

from which the idea of quadraticity follows: the total capital of the surviving collective is equal to $nK_S = n^2 K_i$. The worse the living conditions, the greater the effective (enhanced) human capital K_S should be adequate to them. The smaller the human capital of an isolated person K_i, the larger the size n of family community is necessary for survival, and vice versa.

Under favorable conditions, the large additional force of the large solid collective (team) allows creating prosperity or even an excess of food, we emphasized this revelation of archaeologists when they compared ancient households of different sizes (Douglass, Gonlin, 2012a). Maybe the personal experience of our readers does not allow them to agree with the strong quadratic non-linearity contained in formula (1), but real estimates should take into account the measure of correlation too. Formula (1) explains the reason for the association of people: the productivity of a solid team is significantly greater than the sum of productivities of the people who make up this team. Commenting on formula (1), it should be noted that the concept of human capital as a personal accumulation is particularly effective in theory. We suppose that this concept should involve any useful spiritual and material accumulations of surviving people, including health, housing, the ability to correlate labor efforts and self-discipline.

The strengthening of personal opportunities through collective labor results in a 'social burden' on each member of the family community: the larger the community, the greater the social burden, which is identical to labor. The amount of labor also depends non-linearly on the size of the collective (by means of logarithm in our model), so a solid collective is useful even if it is small: the quadratic effect is greater than the logarithmic labor costs (Privalov et al., 2016). Since labor is tedious, the average size of family communities should be minimally sufficient for survival. It is not easy to find the original source of the idea of laziness as the engine of human evolution, but here we apply namely this very old idea.

As discussed, by the beginning of modern era, the military mission of households is losing its relevance. And at the same time, the need to maximize the size of households is also lost. As regional populations cooperate, the inhabitants of the nearest regional populations, and through them the entire current population of mankind, participating in the exchange of goods, people, and technologies, becomes a source of the personal knowledge and experience applicable for survival. 'Isolated' human capital K_i in the modern era gets the opportunity for significantly more intensive growth. In the genus-tribal era, the positive interaction of social structures (family communities, genera, tribes) was limited by the area of 'paradise lands', where ethnic groups were formed. In the modern era, the positive interaction of regional populations becomes global, and as a result, humanity has formed. At the junction of eras, there is a radical expansion of the area of physical space where social interaction takes place. We can say that at the junction of eras, the large-scale physical space becomes transparent for social relations, just as once the expanding Universe became transparent to light.

It should be mentioned that the description given here suggests a radical difference in the evolution of humans and animals. The combination of friendliness and aggressiveness in the mutual relations of regional populations forces new populations to develop new, even less fertile, lands and keep them with the help of neighbors. A population of animals, just like humans, competes with another population of the same species for fertile land, but cannot help another population to start a new life on a new less productive land, because animals are very limited in their ability to transfer boons, knowledge, and experience.

So, in the modern era, the 'isolated' human capital K_i under the influence of the world experience of survival is growing rapidly. What historical changes are experienced by other parameters of our analytical modeling: the capital K_S and size n related by the formula (1)?

The answer to this question is given in Appendix 1, where we propose and motivate the hypothesis about the historical immutability of capital K_S, and based on this trend we come to the conclusion about the historical reduction in size n. According to the empirical data presented by us, the average size of households n is dependent on the same dimensionless historical time $(T_0 - T)/\tau$ as the global population is experiencing. For this reason, as well as by virtue of the ratio (1), human capital K_i also becomes dependent on dimensionless historical time. Thus, both characteristics (the average households' size and the average human capital of an isolated surviving person) turn out to be the indicators of historical time, almost synchronous in the modern era.

We draw the attention of colleagues and critics to the fact that, using the example of building a house, we were able to show theoretically that the quality of life provided by the family community through collective work in conditions of limited time worsens as we go deeper into the past and improves as we approach our time. The reason is the historical growth of survival productivity in a combination with a non-linearity of the labor collective.

Looking at the initial assumptions and final results, we note the plausibility of overall picture of entities interaction we have considered. Indeed, the historical growth of mankind $N(T)$, human capital $K_i(T)$, and the number of households $M(T)$ are as certain as the historical decline in size $n(T)$. The effectiveness of a solid collective and the associated strengthening of human capital K_i are also undeniable. Even if we assume that the effective capital K_S as the source of minimal flow of boons does not persist, but increases slightly in historical time, this growth is in any case much slower than the historical growth of 'isolated' human capital $K_i(T)$. The decay of households is theoretically reliable, and it is driven by the progress of knowledge and experience, behind which the growing number of inquisitive and friendly people $N(T)$ stands.

Checking all possible consequences of a new theoretical scheme is one of the ways to verify it; in any case the analysis of possible consequences helps us to falsify it easier. To this end, we made an attempt to model the growth of number of households in the genus-tribal era, as a result of which the regional populations were formed. We proceeded from the discussed symmetry of households in the genus-tribal era and regional populations in the modern one. For this reason, we have twice (but with different parameters) applied the hyperbolic formula to simulate demographic evolution to its full depth, i.e. from the beginning of settled survival to the end of global population growth. The results are presented in Appendix 2.

Discussion

If we try to give an answer the problem of theoretical verification of the not quite reliable empirical model of the linear decline in the size of family communities, we can say that it is generally confirmed (see Appendix 1). Mutually consistent models of hyperbolic growth over the course of two eras appear to be similar to reality too (see Appendix 2). Nevertheless, we tend to be cautious about the too-simple relationships of demographic entities that we have obtained, and we intend to focus on their analysis.

In our models, we used mathematical images of such essential subjects of social evolution as family communities (settled herds of primitive people) and regional populations (unions of tribes), between which genera and tribes were naturally located. In an attempt to motivate the elegant simplicity of the hyperbolic growth equations proposed by Kapitza and his predecessors, we were forced to recognize as real a long genus-tribal era, during which regional populations are formed – the very ones that at the second stage of evolution bring humanity to the maximal possible size. The price that had to be paid for the two-eras model was a significant decrease in the speed of human growth at the turn of the eras change and a reduction in the total time of social evolution to about 20,000 years (see Appendix 2). Due to the concretization and decisive expansion of the list of harmonized entities, we significantly expand the scope for criticism from specialists, primarily historians and demographers. Attracting the attention of colleagues to the mechanisms of social evolution is the ultimate goal of our work.

In contrast to Kapitza's regional population, the labor community (family, household) was a cross-cutting category for the entire range of social history from large primitive herds to households with size of 1. The main property of social evolution of the family community (or the household) during the modern era is the historical decrease in its size. In the course of their evolution, households first attract everyone they can, including servants, slaves, captives and distant relatives. In the middle of the disintegration process, parents, their adult children and grandchildren live and work together in 'extended families'. As the final of evolution approaches, 'nuclear families' appear, and then single-parent families, 'families of choice', and increasingly the childless single-person households take place. Demographers and evolutionists tend to find many transitional types and nuances in the process of households' decay. Nevertheless, within the

modeling we have undertaken, the households' decay has been demonstrating its homogeneity for approximately the last 6 thousand years.

A linear function in the humanitarian process is an amazing phenomenon, especially when we consider that the parameter (time in this case) changes more than a hundredfold in natural units. According to our modeling, this happens as follows. In the modern era, the average human capital of an isolated surviving person is proportional to the current number of people $N(T)$, which in turn is a hyperbolic function of historical time. Human capital becomes the same function of time $K_i(T) \approx K_S \tau / (T_0 - T)$ as we showed in Appendix 1. But it and the average size of surviving households consist in inversely proportional interdependence, which gives rise to a linear law of decay $n(T) \approx (T_0 - T)/\tau$.

It would seem that the growth of humanity and the households' decay are connected only by a 'thin thread' of information exchange $K_i(T) \sim N(T)$, but the kinship of these phenomena turns out to be deeper. The force of a household is proportional to the square of the number of its members (Privalov et al., 2016), for example, we assume that the self-recovery speed of a household affected by a crop failure, war or epidemics will be proportional to the square of its current size. Similarly, the force of the genus will be proportional to the square of households' number, and the force of the tribe will be proportional to the square of genera's number. The force of humanity is proportional to the square of regional populations' number, so the speed of growth of the number of regional populations (when the Earth's surface is settling) is proportional to the square of their current number. This is how we come to Kapitza's idea of regional populations. If we now take into account that all regional populations have similar sizes, then the formula for the hyperbolic growth of the number of regional populations proposed by Kapitza is simply and correctly converted into the formula for the hyperbolic growth of the entire population of the Earth proposed by Foerster and his colleagues. Thus, in our study, the quadratic nonlinearity of humanity and the quadratic nonlinearity of the labor collective, generated by the binary interactions of the elements of their internal structure, met.

It is easy to see that the quadratic nonlinearity of all subjects of social structure from households to humanity allows the random (arbitrary) division of these structures by size: the force of genus depends not only on the number of households included in it, but also on their size, because in the end it is proportional to the square of the number of people. The same applies to the tribe, Kapitza's population and humanity as a whole: each of them has a force (power, strength, ability) proportional to the square of the number of people controlled by it. For this reason, the phenomenon of quadratic nonlinearity of a solid family community (Privalov et al., 2016) is included in the phenomenon of quadratic nonlinearity of humanity growth $\dot{N} \sim N^2$ as its first link. It follows that the speed of humanity growth will not be similar to N^2 if the same quadratic nonlinearity does not take place in households! The quadratic nonlinearity of mankind growth speed discovered by Foerster verifies the quadratic nonlinearity of a solid collective. At the same time, the phenomenon of better nutrition of participants of large Mayan households, discovered by the experts of Douglass' and Gonlin's project, proves the nonlinearity of a solid collective, but does not specify the type of this nonlinearity.

When Kapitza estimated the maximal number of regional populations as $\sqrt{N_0}$, then he actually calculated the geometric mean of two comparable and competing multipliers which in this case are the maximal possible number of these populations on Earth and the average number of people in their composition. The calculation of the geometric mean value is not a reliable way to identify the size and number of Kapitza's populations, but it allows us to establish their expected characteristics which turned out to be surprisingly close to the real ones. Let us note that the huge force of labor collectives and all other social structures erected over them is a social capital that uses spiritual entities (responsibility, diligence, discipline) and very small relative material costs (Loshchinin, Privalov, 2016). Social capital is proportional to the square of the number of correlated (mutually dependent) people, so the speed of humanity growth is actually in a linear relationship with its total social capital which can be said to be the human spirit. And again, it must

be recognized that the average social capital of households, as well as of equal-size labor collectives in industry and in all other social structures, is the first multiplier for calculating the social force of humanity as a whole. If the social force of the first basic social unit suddenly disappears, then the force of all the others will disappears too or becomes useless.

Information exchange aimed at the growth of human capital $K_i(T)$ can be interpreted as the historical development of personal survival technologies (Kremer, 1993; Korotayev, Malkov, 2016) where models of hyperbolic growth of the global population and the global economy under the influence of technology development are studied. At the same time, the humanity is assumed to be homogeneous (structures such as households, genera, tribes, and regional populations are not considered) and single-phase (the difference between survival and prosperity is ignored). For this reason, the evolution of social structure was beyond the modeling. We tried to overcome this drawback.

Within the theoretical schemes proposed by Kremer, Korotaev, and Malkov, a linear or monotonous relationship between the progress of technologies and the size of global population is proclaimed. For example, Kremer argues that "the growth rate of technology is proportional to total population". However, we should emphasize the distinction. The mentioned article by Korotaev and Malkov provides a theoretical justification for the previously discovered dependence of world GDP on historical time in the form of a quadratic hyperbolic function. According to our modeling, the world GDP of the surviving part of population should be in a linear relationship with the global surviving population and will depend on time as a simple hyperbole.

In modern humanitarian literature, the distinction between rural family survival and urban individual prosperity is not emphasized. Meanwhile, in our concept, this difference is radical. Labor productivity in cities is always higher due to the phenomenon of 'running away from survival' or 'self-heating' (Privalov et al., 2016), so the size of urban households is always smaller than rural ones. The emission of the working-age population from rural households to cities has been restrained for thousands of years by the phenomenon of 'locked survival' (Privalov et al., 2016), which allowed humanity to settle over the Earth, but by the end of modern era, the increased productivity allows peoples to overcome locked survival everywhere. There is a mass internal migration of the population from villages to cities – what is called urbanization, industrialization and national demographic transitions. At the same time, individual employment in the personnel of enterprises becomes predominant, urban families finally cease to be an instrument of life and lose their necessity; rural families are also approaching degeneration. The global demographic transition has been held back for some time by delayed demographic transitions in developing countries, from where the working-age population migrates to developed countries, but eventually the global degeneration of households will still take place, and the growth of humanity will stop.

Households' decay, which has been going on for about 6 thousand years, should be perceived as ethically positive because it reduces interdependence of people, increases personal freedom, and also because it is associated with easier survival. Households' decay is irreversible because it increases the entropy, i.e. the logarithm of the number of possible ways of collective survival. Nevertheless, the decay of households is extremely dangerous precisely because its final result is the disappearance of the minimal structural units of society. Recall that the archaeologists in the project of Douglas and Gonlin developed the same idea of household as a social unit (Douglass, Gonlin, 2012a). When the decaying households reach the size of irreversible depopulation (about 4), this happens unnoticed for the particular states, ethnic groups and humanity as a whole, because the reaction comes with a great delay. And only the approach of average households' size to the fatal 1 induces in society an increasing number of less and less tolerable problems that arise in real time.

Our civilization is very skilful, including in matters of social risks minimizing. Among the methodologically important ones, we note the article (McKinley et al., 2021), devoted to the interdisciplinary problem of risk management in the conditions of unspecified uncertainties, when even the list of threats is not fully defined. Nevertheless, we point out that the collapse of households will create a unique mass stress in society, when every single household, i.e. every person, including all managers trying to overcome the risk, will become a source of socio-economic risk.

How have households reduced and continue to reduce their sizes? The reduction seems to have been made first by the emission of household members to genus and tribal military units,

to cities for handicrafts, and by the emission of fragments of old family communities into new communities that were developing new lands. The mentioned delay in fertility for a time of 2τ years (Byalko, 2020) in the context of historically increasing survival productivity means a permanent reserve of the number of household participants, which can be used to overcome temporary external problems or for emission. Closer to our historical time, when participants of rural households became increasingly overweight, the reduction in average households' size could occur as a result of a decrease in male and female fertility (Pervova, Starikova, 2020).

It is possible that the degeneration of family communities through prosperity has several mechanisms that reliably guarantee a sad result. In this regard, it is appropriate to recall the numerous experiments of J. Calhoun, when ideal conditions were created for the reproduction of rats or mice, but each time their populations didn't use all provided opportunities, stopped the growth, and then degenerated (Calhoun, 1962). The cause of degeneration was social rather than biological. Calhoun argued that high population density provokes degeneration. We doubt this hypothesis at least in relation to people, because the density of living since the time of 'long-houses' has been decreasing rather than increasing historically. We assume that the danger lies in a growing abundance of food when $K_i \leftrightarrow K_S$. Populations of rats and mice in conditions of full provision with the food and other boons for survival showed an increase in signs of social degradation: the collapse of families, indifference to reproduction and to offspring, the growth of individualism and aggressiveness which are well known in modern societies.

The natural division of eras which we needed to describe the evolution of households is largely consistent with the traditional ideas of historians. The genus-tribal era is not only the time of formation of Kapitza's populations and the rapid growth in the number of family communities with maximal sizes, but also the time of slow growth of human capital and innovations (discussed further) and, as the result, the women's family control. The latter was unanimously noted by historians. The modern era we have introduced is not only a time of rapid growth in the number of Kapitza's regional populations, but also the time of collapse of genus-tribal system, rapid growth of human capital and innovations and, as the result, the establishment of patriarchal primacy in households. The latter was also unanimously noted by historians. The concept of two eras that we used turns out to be trivial.

Following Kapitza, in the modern era, the hyperbolic growth of humanity can be associated with the binary interaction of regional populations, as a result of which they are able to generate new populations. As we see, at the same historical time, hyperbolic growth can be associated with the growth of human capital and, through it, with the decline of the average size of households and with the growth of their number. Thus, both binary processes and the accumulation of survival experience are parallel sources of hyperbolic growth of humanity. Each of them increases the entropy of survival, since it increases the number of participants in the corresponding statistical ensembles (aggregates of regional populations and households). As a result, we do not have the opportunity to name the 'general cause' of modern hyperbolic growth, but we state its double reliability and the inevitability of its dramatic culmination in the form of a global demographic transition.

There is no doubt that human capital increased in the genus-tribal era too. Since the size of human communities at that time did not exceed the size of regional population (several tens of thousands of people), the accumulation of knowledge was slow and independent. In each regional population, people rediscovered survival technologies that had already been discovered somewhere. If in the modern era the source of human capital is the entire global population, then in the tribal era this source was several hundred times weaker. The divisor is the number of 'paradise places' which is also the initial number of regional populations. It is doubtful that under these conditions, human capital had a significant impact on hyperbolic growth which should have occurred only as a result of binary interactions of family communities, genera, and tribes.

The reduction in the average size of rural and urban households, we assume, encourages the reduction in the average size of all other small social structures where people act in conditions of mutual dependence. The size of the family 'sets the tone' in the system of sizes of all social structures (Loshchinin, Privalov, 2016). Thus, the historical decline in the average households' size in cities and in rural settlements, as we have mentioned, means a historical increase in the individual's freedom from society. Unfortunately, the humanities consider the growth of personal

freedoms only as an absolutely positive process and ignore its insidious property of eliminating the mutual dependence of people, including in labor collectives and including in unions of men and women for the birth and upbringing of children. Mass infertility for a social reason will become the most severe punishment for people both for their well-fed life and for their freedom from society. For ultra-fast growth and a huge finite population, humanity will pay with the complete destruction of the mechanism of the birth and upbringing of people.

Modern society is so productive that a middle person is able to provide himself alone with the boons for survival and even with much more rich boons for prosperity. The result of extremely high personal self-sufficiency is not only childlessness, but also a growing dislike of society, nihilism, vandalism, etc.; the list of modern ways to deny society seems to be endless.

The non-trivial linear relationship between the average human capital of a surviving person and the current number of all surviving people which, as we assume, takes place in the modern era, is no less fundamental than the linear decay of households with historical time. Apparently, we can add these parameters as indicators of the direction of 'arrow of historical time' and the speed of the time flow. The category of productive forces, which K. Marx promoted as an indicator of social progress, is significantly less convenient to observe than the category of labor productivity promoted by F. Engels. For this reason, the labor productivity can also be included in the list of 'arrows of time', despite its almost obvious correlation with the growth of human capital, i.e. the growth of personal knowledge and experience (and other useful accumulations) necessary for survival. Let us note our admiration for Engels' intuition: he has always associated the growth of labor productivity with the development of private property (Engels, 2004: 26, 150, 152), just as we had to do when we combined these categories within the modern era. Private property was a consequence of the withdrawal of households from the genus-tribal system. However, Engels did not study the labor communities, just as Morgan did not notice them.

Thus, the historical time of mankind can be indicated by the following unidirectional processes and categories.

1) The growth of the entropy of survival.
2) The increase in the number of surviving people.
3) The decrease in average size of surviving households (in the modern era).
4) The increase in the number of surviving households.
5) The growth of average human capital of surviving people.
6) The increasing personal productivity in creating the boons for survival.

Note the relationship of all these 'arrows of historical time' with the growth of entropy of survival, which means that none of these 'arrows' can be turned back while modern mankind is struggling for survival.

Each of these arrows of time can be an indicator of the age of nation or ethnic group on a historical scale, and the age is calculated not from 'infancy', but from 'extreme old age', achieved during the demographic transition. For example, if the average households' size in nation or ethnic group is $2 \div 3$, this is the time of the beginning of demographic transition, the time of economic stagnation, a change in ethnic composition of states and labor immigration. If the average households size is $3 \div 4$, this is the time of urbanization and rapid economic growth. If the size is $4 \div 6$, this is the time of 'last harmony', when the developed industry of cities and the population growth from rural households are combined. If $6 \div 8$, this is the time of 'enlightened monarchies' and the first bourgeois revolutions. If $8 \div 12$, this is the time of feudal power, etc. The deeper into the past, the larger the average households' size, and the wider the range of sizes.

The larger the average households size, the younger the nation or ethnic group. If the old and young nations or ethnic groups are connected in a humanitarian way (through intensive human contacts and migration), then for historically short time the young nation or ethnic group will age, that is the average size of their households will decrease. The extremely old nation not only loses the ability to reproduce its population, but becomes unable to maintain the labor-intensive activities and is in dire need of the immigration of economically active population from the younger nations or ethnic groups.

There is a close and heuristic analogy with the aging of a person: the old age of a person, like the old age of nation or ethnic group, consists primarily in the loss of reproductive function. Extreme old age or senility consists in the loss of legal and physical capacity; an extremely old person or nation aren't able to fully perform vital functions and are in urgent need of external help.

Old age and decrepitude aren't the best time in individual and social evolution. It is high time to develop social gerontology as the aggregate of objective knowledge about aging and decrepit societies in order to alleviate their suffering.

Strictly speaking, all the arrows of unidirectional processes operate until the beginning of the global demographic transition, which is already close to its middle. All the characteristics of historical time that we have mentioned have already reached their extreme values or will reach them in the foreseeable future. Continuing the images of chronology, we can say that the historical time of mankind is close to a standstill. Let us emphasize at once that we do not share the motivation of the "end of history" proposed by F. Fukuyama, however we are willing to stand by the flag he raised (Fukuyama, 1992): the state that is likely to be reached by humanity in the nearest century may well be regarded as the end of history. The time has come to talk about the possible end of our generation of mankind, and intuitive analysts have long felt this.

S. Kapitza proposed to divide historical time into unequal intervals, during which an equal number of people lived (Kapitza, 2004: 109-139). This seems to be correct, since people are the creators of events, and an equal number of events have occurred in equally populated time intervals. If the population of the Earth begins to decline too rapidly, then new intervals of historical time will not occur due to the lack of sufficient number of people and events, and time will literally stop.

Let us emphasize the fundamental indisputable conditions of social evolution – they are the presence of a start from the animal state and unidirectionality. For this reason, the question of finiteness of the mankind in time turns out to be, if not mandatory, then quite legitimate. In any case, science does not know entities that are not limited in time.

3. Conclusion

The households' decay is an objective worldwide unidirectional process, akin to all other known processes that form the arrows of historical time of mankind: the growth of the world's population, the growth of individual labor productivity, the growth of the number of households. The average household decreases its size at an almost constant rate of about 0.02 people per year, or, in other words, the average household loses one person during the average life expectancy. A possible reason for the historical decrease in average households' size lies in the historical growth of human capital or personal productivity of surviving people, as a result of which the need for people to unite with other people in labor communities (households) is historically decreasing. Theoretical modeling allows us to conclude that in the modern era (approximately the last six thousand years), thanks to information exchange, the human capital of surviving people is in a linear relationship with the current number of Earth's inhabitants and in a monotonous relationship with the entropy of survival. As a result, the households' decay becomes an irreversible, unavoidable social phenomenon.

In the modern era, the strengthening of information exchange, the growth of personal productivity and human capital consistently reduce the size of surviving households and thereby free people from the need for intensive collective labor and from significant mutual dependence for the sake of survival. The historical households' decay means an increase in personal freedoms and should be recognized as ethically positive. However, the final result of households' decay is the disappearance of the institution of family, the termination of the birth of children and the family upbringing of their responsibility and diligence, the undermining of stability of social structures parameterized by the average households' size. The final of households' decay is unfolding at the present time and becoming the most critical event in the history of our generation of humanity.

The households' decay turned out to be closely related to the growth of global population; for this reason, we proposed the two-eras scheme of hyperbolic growth of humanity for modeling demographic evolution. Within the genus-tribal era, households have constant or slightly growing sizes, the number of households increases rapidly, as a result the genus-tribal structure is formed and strengthened, the final result of which is the regional populations discovered by S. Kapitza theoretically. During this era, the military mission is transferred from households to the regional population and thus the restriction on reducing the size of households is removed. In the modern era, on the contrary, regional populations have constant or slightly growing sizes, and family communities begin their historical decay up to households with a size of 1. The total time required for the implementation of both eras of demographic evolution is significantly less than previous

estimates and is about 20 thousand years. The evidence in favor of the reality of Kapitza's populations is presented. The study is based on the recognition of the special role of survival as a basic manner of life and the labor family collective (household) as a basic social unit.

The threat of a possible uncontrolled depopulation of humanity is immeasurably more dangerous than any other, including the anthropic influence on the climate. Meanwhile, climate problems receive disproportionately more attention from science and governments than demographic ones. A brief analysis of demographers' publications on the problem of households' decay is given in Appendix 3. Since the value of humanity is infinitely great, such obvious danger as the inevitable linear reduction in households' size should attract the active attention of responsible researchers and social management, we hope.

Appendix 1

Modeling the decay of households in the modern era

There is an initial empirical ratio for the rate of households' decay

$$\dot{n}(T) \approx -1/\tau\,, \tag{2}$$

where the constant $\tau \approx 45$ years characterizes the scale of time T in the Kapitza hyperbolic growth equation

$$N(T) = N_0\tau/(T_0 - T)\,. \tag{3}$$

In the last equation, $N(T)$ is the current total number of people, N_0 is a certain large number, close to the maximal possible surviving population of the Earth before the demographic transition, and T_0 is the integration constant of the equation for the quadratic growth rate

$$\dot{N}(T) = N^2(T)/N_0\tau\,. \tag{4}$$

The constant N_0 has a numerical estimate and is equal to approximately 200 billion people multiplied by years and then divided by 45 years, that is, about 4.4 billion people. In the chronology from Christ, the constant $T_0 \approx 2025$ is considered as the middle of global demographic transition, completing the hyperbolic growth. Parameter $T_0 \approx 2000 \div 2030$ is used in articles of different years and different authors (Kapitza, 2004; Foerster et al., 1960). In recent years, publications have begun to appear where, based on empirical data, the maximum of the global population and its subsequent decline are recognized as really possible, but the time of reaching the maximum is called somewhat more distant, specifically $2064 \div 2060$ (Byalko, 2020; UN, 2004).

If the equation $\dot{n}(T) \approx -1/\tau$ is integrated, then we tend to choose the integration constant equal to the same constant T_0 when integrating the growth rate (4), namely $n(T) \approx (T_0 - T)/\tau$. We proceed from the idea that the global demographic transition will provoke many 'singularities' in social theory. However, it is real that $n(1980) \approx 3$, as in the US, but not 1. The formula $n(T) \approx (T_0 - T + 2\tau)/\tau$ which recognizes the delay of the decay by $2\tau \approx 90$ years in relation to population growth would be more adequate. Recall that a similar (by 2τ) phenomenon of delayed fertility in relation to climate variations was previously pointed out (Byalko, 2020). Apparently, the solution to the problem of delay of households' decay is possible within the model of demographic transition from growth to depopulation, which is not yet our task. The decay formula should operate in the modern era for several thousand years, against the background of which the delay by 2τ is not significant, and far from the demographic transition

$$n(T) \approx (T_0 - T)/\tau, \quad (5)$$

this is our answer the announced question about the law of households' decay. Strictly speaking, the dimension $n(T)$ is "person / household", so for attentive readers, formula (5) should be rewritten as $n(T) \approx E(T_0 - T)/\tau$, where E = 1 person/household. For simplicity, we omit the parameter E.

Thus, in the modern era, the decay of households is linear with historical time. Nevertheless, due to the small volume and insufficient completeness of empirical evidences, the formula for the linear decay of households $n(T) \approx (T_0 - T)/\tau$ must be understood and consolidated theoretically. We hope that the phenomenon of the conservation of enhanced individual human capital $n(T)K_i(T)$ in form of effective human capital K_S sufficient for survival, namely

$$K_S = n(T)K_i(T) \approx const, \quad (6)$$

will help us to delve into the mechanism of households' decay. More strictly for attentive readers, $EK_S = n(T)K_i(T) \approx const$ where $K_i(T)$ is the individual 'isolated' capital insufficient for survival. The meaning of the phenomenon of constancy $K_S \approx const$ is the millennia-long immutability of the minimal amount of basic survival boons (simple food, simple clothing and shoes, as well as modest housing) produced by people in joint rural labor.

When we put forward the idea of conservation of effective capital K_S for the historical time, we must recognize it multiple-valued. Indeed, how can we understand the conservation of the boons of survival when the food, clothing, shoes, and housing of the surviving people were indeed changing for the better over the past millennia? Does this mean that the parameter K_S is historically growing, and for the sake of improving the quality of their lives, surviving people overcome additional difficulties? It would be correct to assume that the problems of human survival are unchanging rather than increasing or decreasing. A cup of milk is equally valuable for a surviving person, no matter where the milk is produced and how much it costs and he does not care whether he has to sleep on an armful of hay or a spring mattress. We suppose that the quality of survival is not crucial for understanding social evolution, because the flow of boons is always minimized in survival. The problem of scarcity of the boons and forces for survival accompanies the entire history of mankind up to the present time.

The ratio (6) reflects the historical decline in the average collective efforts to create the main boons of survival in their natural form. Due to the growth of knowledge, experience, and material accumulations of workers, it requires an increasingly smaller team to create a volume of food, clothing and housing in accordance with the minimal requirements of people within each next interval of historical time. Neither monetary spending nor the time ones can be adequate characteristics of the evolution of survival for many reasons, the main one being the non-linearity of the phenomenon of collective labor. For example, it is not enough to say how many man-hours of labor (or just the time) it took to build of a modest rural family house; it is also necessary to specify the factor of strengthening of personal labor, i.e. the average size of household.

Let's suppose that in 1800, a rural family of 6 people could build their own house within two months. Let's ask ourselves: how much time and efforts did it take to build the same house in 800, when the average family (as we assume) consisted of 25 people? The possible answer is as follows. Human capital and personal labor productivity at that time were 25/6 ≈ 4 times less, so 6 people in 800 would have built a similar house for 8 months, but a team of 25 people would have built such a house for the same 2 months. However, the real number of inhabitants in it would be four times more, i.e. 25 people instead of 6. If the 2 months we have named represent the optimal time to build, and the high density of inhabitants is not implemental, then a rural house in 800 should be larger in size, but less labor-intensive (simpler) than in 1800. Of course, such housing provided the worst quality of survival, yet it was compatible with life! Ancient people not only lived very closely,

but often placed domestic animals in their homes. The deeper into the past, the worse the quality of survival is, and vice versa. It is surprising that the phenomenon of historical quality of life variation can be understood theoretically. We do not insist on the accuracy of our estimates, but we suppose it is important to take into account the non-linearity of collective phenomena in history.

If we substitute the empirical ratio (5) into the ratio of conserving the minimal flow of boons (6) and take into account the empirical ratio (3), we get

$$K_i(T) = K_S N(T) / N_0, \tag{7}$$

where the linear relationship between the 'isolated' human capital of a surviving person $K_i(T)$ and the rapidly growing population of the Earth $N(T)$ turns out to be non-trivial. We have to emphasize the consistency of this relation. It is precisely because of inequality $K_i < K_S$ that the force of the solid collective is required. The need for a solid household disappears when $N(T) \to N_0$ and $K_i \to K_S$. Of course, there is a historical growth of human capital:

$$K_i(T) \approx K_S \tau / (T_0 - T). \tag{8}$$

Since knowledge and experience are actually contained in the 'heads and hands' of living people $N(T)$, the linear relation $K_i(T) \sim N(T)$ seems to be the "information exchange", the influence of which on hyperbolic growth of mankind was discussed earlier (Kapitza, 2004: 83-88). Unfortunately, Kapitza did not propose any models or formal schemes of information exchange that would generate hyperbolic growth. If we follow the logic outlined here, then the relation of human capital (knowledge, experience, personal information) with the hyperbolic growth of mankind is carried out by us through the model of the family labor community and through the phenomenon of its decay. It would seem that we have called the indirect and inefficient attributes, but the reduction in size of labor communities turns into a rapid increase in number of these communities and through them stimulates the rapid growth of mankind.

Once again, we emphasize the indisputable, but fundamental thesis that information (the same that is directed to human capital) is contained only in the minds of living people. If for some reason the knowledge is not needed, it quickly disappears, even if it is written somewhere. When a new need happens, the knowledge must be rediscovered; we refer to the forgotten knowledge of the ancient Sumerians, written on clay tablets (Wikipedia, Babylonian).

According to the scheme proposed here, the constructive role of information begins at the moment when the family communities happen in the protective 'shell' of the regional populations and abandon its original military mission. After that, they can use the possibility to reduce their sizes, and the regional populations begin to multiply intensively, filling all the land areas available for survival. At the same time, the genus-tribal system, which has fulfilled its historical mission for creating regional populations, is disintegrating. Princes, barons, dukes, and kings begin to manage the regional populations and their alliances instead of the former tribal leaders. The growth process is completed when all available land is filled ($N(T_0) \to N_0$) or the households are completely decayed ($n(T_0) \to 1$). In our scheme, this happens almost simultaneously. We believe that this is how the 'universal clockwork' acts, counting down the historical time of mankind.

By strengthening the human capital of mutually dependent participants, who work together on unproductive land, the family community turns them into quasi-free inhabitants of an ideally productive territory. The phenomenon of the quasi-free presence of a diligent hard-working participant of surviving community is what we see as the one of meanings of the relationship (6) $K_S = n(T) K_i(T) \approx const$.

If we compare the formulas of households' decay $n(T) \approx (T_0 - T)/\tau$ and the hyperbolic growth of mankind $N(T) = N_0 \tau / (T_0 - T)$, then $n(T) N(T) = N_0$, and similarly $N(T) / K_i(T) = N_0 / K_S$. The growth of mankind is due to the reduction of the average household

size and due to the growth of the human capital of surviving people. The appearance of the parameters $n(T)$, $K_i(T)$, and $N(T)$ in one equation indicates not only their mutual great importance, but also the coincidence of the ranges of their variation because of factors $(T_0 - T)/\tau$ or $\tau/(T_0 - T)$ build in them. If the number of households is denoted by $M(T)$, then $n(T)M(T) = N(T)$ and $n^2(T)M(T) = N_0$, or

$$n(T) = \sqrt{N_0 / M(T)}; \quad (9)$$

the last shows that the number of households $M(T)$ is also included in the pool of significant parameters and is growing faster than the average size decreases. Finally

$$N(T) = \sqrt{N_0 M(T)}, \quad (10)$$

hence it can be seen that the source of the growth of mankind, due to the mutual relationship of the parameter $N(T)$, $n(T)$, $K_i(T)$, and $M(T)$, is the growth of the number of households too. Moreover, the number of households is the fastest demographic parameter.

Let us estimate the ranges of variations. Let the initial maximal household size $n(T)$ be 100 ÷ 160 or an average of 130, while the final minimal size is 1. The same range we must attribute to the population of the Earth $N(T)$ for the modern era which we have identified: $(T_0 - T)/\tau \approx 130$. Thus, our model of linear decay operates approximately $130\tau \approx 6$ thousand years into the past. Human capital $K_i(T)$ acquires the same dynamic range of "130", and this is quite possible estimation. The number of households $M(T)$ in the same time interval will have a quadratic range of "$130^2 \approx 17000$" and its fatal evolution is $M(T) \to N_0$. As we can see, the constant speed of decay is enough to confidently pass through 6 thousand years of retrospect, which now can be said 'they were yesterday'.

Appendix 2

Modeling of hyperbolic growth in the genus-tribal era

The full dynamic range of the parameter $N(T)$ from primitive herds and the first family communities with the mentioned total number of about 100 thousand individuals to the final $N_0 \approx 4.4$ billion people will be about 44 thousand times, while the increase in world's population in the modern era, we estimated as 130 times. It turns out that in the genus-tribal era, the increase in humanity made 44000/130 ≈ 340 times. What was the possible mechanism of this growth? If the Kapitza's regional populations are to be considered real subjects of hyperbolic growth and not a theoretical abstraction, then we must clearly understand how they came to be.

The positive pair relations of family communities within the genus and tribe are of the same nature as positive pair relations of regional populations. So, the theoretical model for the modern era $N(T) = N_0\tau/(T_0 - T)$ can be used to describe the genus-tribal era too. Collective hunt large animals and joint military actions to preserve and expand the 'paradise places' are the more effective the larger the size of family communities. Therefore, in the genus-tribal era, as we suppose, there was a tendency to maintain (and even to some increase) the size of family communities as the subjects of the first hyperbolic growth.

In the new model, the maximal number N_0 will decrease to the average size of the regional populations; let it be equal to 65 thousand people. The time parameter τ meaning of the average life expectancy will have to be reduced to a new more real value, for example to 30 years. According to our estimates outlined in the Appendix 1, the final time is $T_0 \approx -4$ thousand years from Christ. Maybe, the real tribal unions in the genus-tribal era were less populated than Kapitza's populations of in the modern era. For example, Morgan reported a more modest sizes of confederations; for the

Iroquois tribes in the 15th century, it did not exceed 20 thousand people (Morgan, 1907: 127); in the 19th century, for the Creeks, it did not exceed 15 thousand (Morgan, 1907: 165), the Choctas – 12 thousand (Morgan, 1907: 166), the Cherokees – 14 thousand (Morgan, 1907: 168), the Ojibwas – 16 thousand (Morgan, 1907: 171). But we are not sure whether the mentioned confederations of tribes reached their full development or it was interrupted by the invasion of Europeans, so we leave the estimate of the average size of regional populations at the same value equal to 65 thousand people.

So, we assume that the evolution of the family community in the genus-tribal era begins at a single community with a size of 130 people, and ends by the regional population with size of about 65 thousand people. In this case, the dynamic range of the population size in this era will be 500, and the interval of historical time will be $500\tau \approx 15$ thousand years. It follows that our estimate of the duration of the two eras covers the interval "– 19 thousand, – 4 thousand, + 2 thousand" years on the historical scale where zero is the birth of Christ. The full range of changes in the Earth's population in this interval will be $500 \cdot 130 = 65$ thousand times, which is slightly more than the expected value of 44 thousand times. Accordingly, the estimate of the duration of genus-tribal era as 500τ is 1.5 times longer than its expected value of $44000\tau/130 = 338\tau$. Thus, the initial data proposed by us need some adjustment.

It may be that L. Morgan's estimates of the size of confederations of North American tribes will be closer to the real size of regional populations than our estimate of 65 thousand people, lent from the Kapitza's concept. Since the final size of surviving global population at the end of modern era (4.4 billion people) is a plausible value, a decrease in the average size of the regional populations means an increase in the range of global population size in the modern era. According to the above evaluations, this range will also be underestimated by 1.5 times in relation to the range of household size (130 times), so it may seem that we have found an easy way to improve our estimates and can safely reduce the expected size of Kapitza's populations.

Nevertheless, we are increasingly convinced of the objectivity of regional populations; a decrease in their size means an increase in their finite number and a decrease in average area occupied by them. The latter can be verified empirically, but there is not much similar statistics yet. The importance of the time parameter τ with the meaning of average life expectancy for describing the evolution of mankind is also not supported by systematic statistical data. Due to the insufficient amount of empirical data, the parameters fitting would be rather speculative and the detected one-and-a-half-fold discrepancy of evaluations must be recognized as our systematic mistake that can be overcome in the future.

If we were to abandon the genus-tribal era and apply the modern era's parameters to the full depth of social evolution with a dynamic range $44{,}000\tau$, as Kapitza did, we would get a couple of million years of social history. Kapitza's estimation made 1.6 million years. Thus, the recognition of two eras and the special role of family communities significantly lowers the estimates of the total time of social evolution, for example to 20 thousand years.

Of course, the function $N(T)$ in the genus-tribal and modern eras is continuous in time, but the rate of growth $\dot{N}(T)$ should show a break in continuity at the junction of eras. Let the population starts from about 100 thousand people or 770 family communities of 130 people. After 15 thousand years (500τ), at the end of the genus-tribal era, global population reaches approximately $770 \cdot N_0 \approx 770 \cdot 65{,}000 \approx 50$ million people. The number of family communities increases from 1 to 500 in each Kapitza's population, and the number of last is 770. Recall that the information exchange in the model of this era was 'turned off' by us, and this affected the modest growth in the number of family communities. We also recall that the numerical evaluations 500τ and 50 million people may be overestimated by about 1.5 times. We hope also that readers have noticed a change in designation: N_0 = 65 thousand people for the genus-tribal era and N_0 = 4.4 billion people for a modern one. We assume that the parameter of life expectancy at the junction of eras makes an intermediate value of $\tau \approx 35$ years. The rate of mankind growth at the end of the genus-tribal era in 770 regional populations was about $\dot{N}(T) = N^2(T) / N_0\tau$ multiplied by 770,

or about $770 \cdot 65{,}000^2 / 65{,}000 \cdot 35$, or about 1.4 million people/year, but at the beginning of the modern era the rate of mankind growth was about 50²million²/4,4 billion·35 or about 0.016 million people/year.

Thus, at the junction of eras, the rate of mankind growth abruptly decreased by more than 80 times over a period of about $2\tau \approx 70$ years similar to Kapitza's scheme of demographic transition. The reason for the speed jump down is the replacement of the growth subject: small family communities transfer this role to a much larger Kapitza's regional populations at the junction of eras. Similarly, the estimated time of social evolution has been reduced (from 1.6 million years to 21 thousand ones). Accordingly, the space perceived by people has expanded dramatically: from a daily walk to the size of the Earth. The phenomena of jumps in speed and perceived space, as well as the recalculation the time of evolution, are simple mathematically, but it would be interesting to test their reality from the historical data.

Appendix 3

Objections to unjustified optimism

The whole world is currently engaged in a demographic transition. There are still young issuing countries, but there are fewer of them. Their households have decreased even further. There are fewer and fewer demographers who confidently predict the growth of the world's population in the future. When S. Kapitza developed his model of demographic transition, he believed that mankind following the developed countries would reach a high and stable level of population. Unfortunately, he made a mistake which himself warned his colleagues against: mankind is not reducible to ethnic groups, countries or groups of countries.

We do not want to frighten ourselves and our readers by the 'Doomsday', and the final purpose of our article is to draw attention to the very problem of possible finiteness of the mankind, when even the slightest speculative danger would be worthy of serious discussion. Meanwhile, there are many dangers and they are real, but the scientific community does not pay attention to the problem of global degeneration, according to the scale of threat. This is evidenced by the lack of systematic information on the historical change in households' size in most countries and in the most populated regions, as well as the lack of proper theoretical understanding of the evolution of households and mankind as a whole. The unjustified optimism of demographers must be overcome.

We would like to note some publications that express concerns and hopes in connection with the global family crisis. Political economist N. Eberstadt in the article "The global flight from the family" emotionally vividly discusses the problem of family degeneration, pointing to the global nature of this problem and linking it to the irresistible desire of people for convenience and personal autonomy. The author points out the lack of statistical observation of the disappearing family by the states, notes the loss of family education of children and family patronage of old people (Eberstadt, 2015).

In the article by O. Burger and J. DeLong, "What if fertility decline is not permanent?" in addition to a broad overview of the problem of fertility, an attempt is made "to question the assumption that world-wide transition to very low fertility is irreversible" (Burger, DeLong, 2016). Unfortunately, the authors did not find any major objective trends towards confident reproduction of the world population and concluded their analysis with the hope for the success of science: "Interdisciplinary collaboration and appreciation of multiple approaches – including evolutionary theory – will be needed to develop alternative population projections in the future".

Demographers often rely on the rapidly growing technological capabilities of mankind: salvation is bound to come from somewhere! Let us object to them in this way: if salvation comes tomorrow, then today we should see signs and 'sprouts' of a saving future, but they are not there. Optimists cite examples of the preservation of a fairly large part of the population even after pandemics of plague and cholera and argue that people survive more effectively than kitchen cockroaches. They also express their belief in the success of biotechnology and the 'birth of people in a test tube'. As a counter-argument, we would like to point out that the upbringing and education of people are significantly longer and overwhelmingly more labor-intensive compared to

the labor intensity of their possible biosynthesis. For this reason, biotechnology is not in the least able to solve the problem of mankind depopulation.

Even more often they talk about the excessive modern population of the Earth and the reasonableness of its reduction to the 'golden billion'. We suppose that the rationalizers of mankind do not realize the total nature and objectivity of demographic process. When the households finally degenerate and the worldwide depopulation begins, it will not stop at the 'golden billion' mark and will bring the size of mankind to the original number of people in primitive herds that dwelled in 'paradise lands', or slightly larger. Recall this number: about 100 thousand individuals. We expect depopulation 'until zero', because the technologies of family unproductive survival, even in the middle latitudes, have already been lost everywhere, and their restoration in real practice will require a reserve of time and mobilization of forces, which (due to the transience of depopulation) may not be available. We expect a rapid depopulation of humanity, because after the completion of the demographic transition, both parameters with the dimension "people" (the average sizes of households and of Kapitza's populations) will degenerate and only a small time parameter of average life expectancy will remain.

The historical optimism contained in projections "World Population to 2300" issued by the United Nations Department of Economic and Social Affair (UN, 2004) is highly questionable, because of the inexplicable experts' belief in the balance of fertility and mortality. Most of the critical ideas are contained in the same volume in the Essay VIII "Reflections on the next few centuries" (Héran, 2004: 151-158). Sarcastic criticism of the Essay is directed on the position of UN demographers, who tend to consider "that their worst-case scenarios are just as probable as the scenario of stabilization at the exact level of the replacement of generations" (Héran, 2004: 156). It is characteristic that F. Héran concludes his analysis not by pointing out the hidden mechanisms of natural demographic self-regulation, but by hoping for the still unknown achievements of science and the will of future leaders.

We quote: "We prefer to leave nothing to providence or chance: we want to believe that we shall have a say in our future. This leaves the choice between two educational approaches: either the apocalyptic prophesy of Cassandra or Jeremiah ("we are heading towards disaster, repent!"); or faith in the spread of knowledge, following the lead of Bacon and Condorcet ("guided by science, we can act with full knowledge of the facts"). If demographers have good reasons to suppose that equilibrium is the only viable long-term solution for the development of world population, that does not mean that the achievement of this goal is written into the nature of things or guaranteed by some spontaneous and mysterious power of correction. It will depend upon the capacities for action and reaction developed by societies and their rulers" (Héran, 2004: 157).

Does humanity have natural mechanisms to maintain the growth or at least to maintain a constant size of the global population? If we have understood evolution correctly, then in order to restore the reproduction of the population in a natural way, it is necessary to restore households as labor collectives, tear them out of comfortable urban prosperity and lower them to the bottom of rural survival. The difficulties of producing the boons of survival must be great, and the technological possibilities must be small; then households will take an interest in the birth and upbringing numerous child-workers 'in the labor and responsibility'. Figure 1 shows these times: in the United States in 1790 (the year of A. Smith's death), there were almost 6 people in an average family, and society needed even larger families! Here is what Smith wrote in 1776 about widows with children in North America: "A young widow with four or five young children, who, among the middle or lower ranks of people in Europe, would have so little chance for a second husband, is there often courted as a sort of fortune. The value of children is the greatest of all encouragements to marriage" (Smith, 1904: 72, chapter VIII). Is it possible to repeat this natural state of society again? No, of course!

We want to conclude our objections to unjustified optimism with a consonant quote from an article published in 2008 in the Bulletin of the Moscow State University (Medkov, 2008) in connection with next unfounded UN forecast of the global population up to 2050, revised in 2006. "Humanity has already entered the period of depopulation, finding itself in a situation unprecedented before, when all previous ideas about demographic dynamics and its consequences have lost (or are losing) their relevance. An increasing number of countries are embarking on the disastrous path of depopulation. At the end of this path, there is either the disappearance of humanity as such, or its transformation into something similar to the gloomy mechanized utopia of

Aldous Huxley. And let us not be comforted by the thought that this is still far away – this 'beautiful new world', the world of clones, cyborgs and biorobots is already here, on the threshold... And if nothing is done, it will come faster than we think."

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Обнаружение исторического тренда распада домохозяйств

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Аннотация. На основании эмпирических фактов и общего контекста обнаружено, что историческое уменьшение среднего размера домохозяйств происходит с почти линейным законом с величиной приблизительно 0,02 человека в год. Предпринята попытка теоретического обоснования линейного закона распада домохозяйств на основании модели гиперболического роста человечества, сформулированной С. Капицей в терминах специфической единицы времени и эволюции региональных популяций. Предложена и обоснована гипотеза, что линейный распад домохозяйств формирует стрелу исторического времени человечества подобную стреле, какую формирует рост населения Земли. Предложена и обоснована гипотеза о двух эпохах эволюции домохозяйств и населения Земли. В рамках родоплеменной эпохи семейные общины имеют почти постоянные размеры и являются субъектами гиперболического роста. В современную эпоху региональные популяции Капицы имеют почти постоянные размеры и являются субъектами гиперболического роста, а семейные общины начинают свой исторический распад вплоть до домохозяйств с размером 1. Полное время, необходимое для реализации обеих эпох социальной эволюции, существенно меньше прежних оценок и составляет порядка 20 тысяч лет. Информационный обмен в современную эпоху стимулирует рост человеческого капитала и последовательно освобождает людей от необходимости коллективного труда ради выживания, и по этой причине он назван возможной причиной распада домохозяйств.

Ключевые слова: распад домохозяйств, эволюция домохозяйств, размеры домохозяйств, семейная общность, трудовой коллектив, демографический переход, стрела исторического времени.

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