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**Unified Growth Theory Contradicted by the
Mathematical Analysis of the Historical Growth of
Human Population**

By Ron W. NIELSEN [†]

Abstract. Data describing historical growth of human population, global and regional (Western Europe, Eastern Europe, Asia, former USSR, Africa and Latin America), are analysed. Results are in harmony with the earlier analysis of the historical growth of the world population in the past 12,000 years and with other independent studies. This analysis is also in harmony with the study of the historical economic growth. Within the range of analysable data, there was no Malthusian stagnation. Takeoffs from stagnation to growth, postulated by the Unified Growth Theory never happened. There were no escapes from the Malthusian trap because there was no trap in the growth of population. This analysis and the earlier studies of the Gross Domestic Product lead to the conclusion that there were also no takeoffs in the income per capita distributions, claimed by the Unified Growth Theory. Consequently, the claimed differential timing in takeoffs never happened. Unified Growth Theory is contradicted yet again by the mathematical analysis of the same data, which were used, but never analysed, during the formulation of this theory. The study presented here, as well as earlier publications on the related topics, shows also that certain fundamental postulates used in the economic and demographic research are repeatedly contradicted by the mathematical analysis of data.

Keywords. Population growth, Economic growth, Unified Growth Theory, Regimes of growth, Malthusian trap, Gross Domestic Product, Income per capita, Hyperbolic growth.

JEL. A10, A12, B41, C50, F00, F01, Y80.

1. Introduction

Historical economic growth can be studied using the Gross Domestic Product (GDP). However, to understand the time dependence of the income per capita (GDP/cap) it is necessary to understand not only the economic growth, expressed in terms of the GDP, but also the growth of human population. We have already analysed the GDP data (Nielsen, 2016a; 2016b; 2016d). Now, we shall analyse the growth of human population using the same source of data (Maddison, 2010). The aim of these studies is to investigate the validity of the Unified Growth Theory (Galor, 2005a; 2011) and to understand the mechanism of growth as revealed by data because the correct interpretation of the historical growth can help in the correct interpretation of the current economic growth and of the growth of population.

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Our earlier analysis (Nielsen, 2016a; 2016b; 2016d) demonstrated that the historical economic growth, regional and global, was hyperbolic. Thus, if unchecked, the natural tendency for the economic growth is to follow hyperbolic distributions. This type of spontaneous growth is undesirable because hyperbolic distributions escape to infinity at a fixed time. To avoid such a rapid and potentially catastrophic increase economic growth has to be closely monitored and controlled.

Analysis published over 50 years ago (von Foerster, Mora & Amiot, 1960) demonstrated that the growth of the world population was also hyperbolic during the AD era. The follow-up analysis (Nielsen, 2016c) demonstrated that the growth of the world population was hyperbolic not only during the AD era but also during the BC era, for the total of around 12,000 years. This particular analysis identified two demographic transitions in the past growth of the population: between 500 BC and AD 500 and between AD 1200 and 1400. However, these transitions were of a different kind than the transitions assumed routinely in demographic research. They were not transitions from stagnation to growth but from growth to growth, or more precisely, from hyperbolic growth to hyperbolic growth. The first transition was from a fast hyperbolic growth during the BC era to a significantly slower hyperbolic growth during the AD era. During this transition, the size of human population reached a maximum around AD 1 and after reaching a minimum between AD 400 and 500 it resumed its slower hyperbolic growth during the AD era. However, the starting size of global population in AD 500 was significantly larger than in 10,000 BC and the slower hyperbolic growth increased rapidly to reach a large size of the population in only about 2000 years. During this first demographic transition, the growth rate *decreased* from 0.252% in 500 BC to 0.066% in AD 500. The second transition was hardly noticeable but it resulted in a change from a slow hyperbolic trajectory to a slightly faster hyperbolic trajectory. During this transition, after a short delay in the growth of the population, the growth rate *increased only marginally* from 0.123% in AD 1200 to 0.157% in AD 1400. Currently the growth of the world population experiences a third demographic transition to a yet unknown trajectory.

2. Unified Growth Theory

The latest and the most elaborate theory describing economic growth is the Unified Growth Theory (Galor, 2005a; 2011). It is not a theory, which is widely accepted by economists and used in their research. In fact, the opposite seems to be true. However, we are using this theory *as an example* for two reasons. *First*, it is a theory, which is firmly based on traditional but erroneous assumptions about the historical economic growth and about the historical growth of human population. Our primary aim here, the same aim we had in earlier publications (Nielsen, 2014; 2015a; 2016a; 2016b; 2016c; 2016d; 2016e), is not just to test the validity of this theory or the validity of a similar Demographic Transition Theory (see Nielsen, 2016e and references therein) but to test the validity of the *fundamental postulates* used in the economic and demographic research. *Second*, Unified Growth Theory appears to be the only theory where Maddison's data (Maddison, 2001) were used systematically but unfortunately they were never analysed. They were manipulated and distorted to support preconceived ideas. Now, *precisely the same data* can be used to show that the preconceived ideas used and promoted in this theory are incorrect (Nielsen, 2014; 2015a; 2016a; 2016b; 2016d). Here we have a difference between a study based on the manipulation of data and a study based on the rigorous analysis of data.

In the last years of his life, Magnusson, the world-renowned economist, published excellent data describing not only the economic growth as expressed by the Gross

Domestic Product (GDP) but also the growth of human population, global, regional and national (Magnuson, 2001; 2010). These data are a treasure trove, which can be used in the economic and demographic research. In particular, they can be used to test the fundamental postulates supporting these two fields of research. Galor used the earlier compilation of these data (Magnuson, 2001) but any of them can be used to test the fundamental postulates supporting economic and demographic research, and in particular to test the validity of the Unified Growth Theory.

Unfortunately, this theory and its fundamental postulates are based on the habitually distorted and self-misleading presentations of data (Ashraf, 2009; Galor, 2005a; 2005b; 2007; 2008a; 2008b; 2008c; 2010; 2011; 2012a; 2012b; 2012c; Galor & Moav, 2002; Snowdon & Galor, 2008). This counterproductive approach to research was used to promote such scientifically-unsupported concepts as the concept of the three regimes of growth (Malthusian regime of stagnation, post-Malthusian regime and sustained-growth regime), the concept of sudden takeoffs from stagnation to growth, the concept of differential timing of takeoffs and the concept of the great divergence. An example of the strongly deceptive and misleading diagrams used in the Unified Growth Theory and in other related publications is shown in Figure 1. (All diagrams are presented in the Appendix.)

Hyperbolic distributions do not have to be distorted to be confusing. They are already sufficiently confusing and it is easy to make mistakes with their interpretations. Hyperbolic distributions have to be carefully and methodically analysed and fortunately their analysis becomes trivial when using the reciprocal values of data (Nielsen, 2014). Displays, such as presented in Figure 1, which is based on a figure presented by Galor (2005a, p. 181), are self-misleading and they inevitably lead to incorrect conclusions.

The correct and accurate display of Maddison's data (Maddison, 2001), precisely the same data as used but never scientifically analysed during the formulation of the Unified Growth Theory (Galor, 2005a, 2011), is presented in Figure 2. Analysis of these data reveals that they follow *monotonically-increasing* distributions, which are impossible to divide into distinctly-different regimes of growth governed by distinctly-different mechanisms (Nielsen, 2014; 2015a). There was no stagnation and no transition from stagnation to growth. There was no escape from the Malthusian Trap because there was no trap in the economic growth.

Whether expressed by using the GDP or GDP/cap, economic growth was slow over a long time and fast over a short time but it was monotonically increasing all the time. What appears as stagnation was a part of the monotonically-increasing distribution, and what appears as a sudden takeoff was the natural continuation of the same monotonically-increasing distribution.

Attempts to determine the time of the perceived transition from slow to fast growth are bound to be unsuccessful because there was no transition (Nielsen, 2014; 2015a). The growth of the GDP is described by hyperbolic distributions (Nielsen, 2014; 2016a) and the growth of the GDP/cap by the linearly-modulated hyperbolic distributions (Nielsen; 2015a).

One of the fundamental postulates of the Unified Growth Theory is the postulate of the existence of three regimes of growth governed by three distinctly different mechanisms: (1) the Malthusian regime of stagnation, (2) the post-Malthusian regime, and (3) the sustained-growth regime. This postulate applies not only to the growth of the GDP but also to the growth of human population because Galor discusses the growth of income per capita, (GDP/cap), which is made of two components: the growth of the GDP and the growth of population.

According to Galor (2005a; 2008a; 2011; 2012a), Malthusian regime of stagnation was between 100,000 BC and AD 1750 for developed regions and

between 100,000 BC and AD 1900 for less-developed regions. The claimed starting time appears to be based entirely on conjecture because Maddison's data are terminated at AD 1 and even they contain significant gaps below AD 1500. The post-Malthusian regime was allegedly between AD 1750 and 1850 for developed regions and from 1900 for less-developed regions. The sustained-growth regime was supposed to have commenced around 1850 for developed regions.

Unified Growth Theory (Galor, 2005a; 2008a; 2011; 2012a) can be tested in many ways but the easiest way to test it is to look for the dramatic takeoffs from stagnation to growth. These takeoffs are described as a "remarkable" or "stunning" escape from the Malthusian trap (Galor, 2005a: pp. 177, 220). It is a signature, which cannot be missed.

This change in the pattern of growth is described as "the sudden take-off from stagnation to growth" (Galor, 2005a: pp. 177, 220, 277) or as a "sudden spurt" (Galor, 2005a: 177, 220). According to Galor, for developed regions, the end of the Malthusian regime of stagnation coincides with the Industrial Revolution. "The take-off of developed regions from the Malthusian Regime was associated with the Industrial Revolution" (Galor, 2005a: p. 185). Indeed, the Industrial Revolution is considered to have been "the prime engine of economic growth" (Galor, 2005a: p. 212).

The signature of takeoffs is characterised by three features: (1) it should be a prominent change in the pattern of growth, (2) it should be a transition from stagnation to growth and (3) it should occur at the time predicted by the theory. For developed regions, the postulated takeoffs should occur around AD 1750, or around the time of the Industrial Revolution, 1760-1840 (Floud & McCloskey, 1994). For less-developed regions, they should occur around 1900. The added advantage of using this simple test is that there are no significant gaps in the data around the time of the postulated takeoffs and consequently the stagnation and the expected prominent transitions from stagnation to growth should be easily identifiable.

A transition from growth to growth is not a signature of the postulated takeoff from stagnation to growth. Thus, for instance, a transition from hyperbolic growth to another hyperbolic growth or to some other steadily-increasing trajectory is not a signature of the sudden takeoff from stagnation to growth. Likewise, a transition at a distinctly different time is not a confirmation of the theoretical expectations.

The takeoffs claimed by Galor are in the income per capita (GDP/cap), which means that there should be takeoffs from stagnation to growth in at least one of these components (in the GDP or in the population or in both of them) at a specific time (Galor, 2008a; 2012a). We have already demonstrated that the Unified Growth Theory is contradicted by the GDP data describing the world economic growth as well as the economic growth in Western Europe, Eastern Europe, countries of the former USSR, Asia, Africa and Latin America (Nielsen, 2016a; 2016b; 2016d). We have also demonstrated that the Unified Growth Theory is contradicted by the data describing the growth of the world income per capita (Nielsen, 2015a). Our next step now is to extend our analysis to the growth of population and thus to extend our study of income per capita, not only global but also regional.

We have already demonstrated that there were no takeoffs in the growth of the GDP. Consequently, to confirm the Unified Growth Theory we would have to show not only that there were takeoffs from stagnation to growth in the growth of the population but also that these takeoffs occurred at the specific time claimed by Galor (2008a; 2012a), around AD 1750 for developed regions (Western Europe, Eastern Europe and the former USSR) and at around AD 1900 for less developed regions (Asia, Africa and Latin America). We shall now demonstrate that there

were no such takeoffs. Thus we shall demonstrate implicitly that there were no takeoffs in the income per capita, which means that Galor's postulate of the differential timing in takeoffs is also contradicted by data, because we cannot have differential timing in takeoffs without takeoffs.

3. Essentials of the mathematical analysis

Hyperbolic distribution describing growth is represented by a reciprocal of a linear function:

$$S(t) = \frac{1}{a - kt}, \quad (1)$$

where $S(t)$ is the size of the growing entity, in our case the population, while a and k are positive constants.

As pointed out earlier (Nielsen, 2014), hyperbolic distributions are confusing because they create an illusion of being made of two components, slow and fast, with perhaps even a third component in the middle. It is easy to make a mistake with their interpretations. Fortunately, these distributions are easy to analyse by using the reciprocal values of data, $1/S(t)$:

$$\frac{1}{S(t)} = a - kt. \quad (2)$$

In this representation, data follow a decreasing straight line, which obviously cannot be divided into two or three distinctly different components.

Reciprocal values help in an easy and generally unique identification of hyperbolic growth. Apart from serving as an alternative way to analyse data, reciprocal values allow also for the investigation of even small deviations from hyperbolic distributions because deviations from a straight line can be easily noticed.

The illusion of different components also disappears when using semi logarithmic scales of reference. Both types of displays help in an easy identification of disagreements between data and fitted curves for small values of data and we shall use both of these displays.

4. Growth of the world population

Results of mathematical analysis of the world population are presented in Figures 3 and 4. Reciprocal values of historical data identify uniquely hyperbolic distribution between AD 1000 and around 1950 because they follow a decreasing straight line. From around 1950, the growth of the world population started to be diverted to a slower trajectory but first it was slightly boosted. The boosting was small (it is hardly noticeable in the displayed diagrams) and it did not last long.

Hyperbolic fit to the world population data (Maddison, 2010) is shown in Figure 4. The fit is remarkably good. The point at AD 1 is 75% higher than the fitted curve. This discrepancy is in perfect agreement with the analysis of the growth of the world population over the past 12,000 years (Nielsen, 2016c), which demonstrated a maximum around that year.

Parameters describing hyperbolic trajectory fitting the data between AD 1000 and 1950 are: $a = 7.739 \times 10^0$ and $k = 3.765 \times 10^{-3}$. Its singularity is at $t = 2056$. However, from around 1950, the growth of the world population started to be diverted to a slower trajectory bypassing the singularity by a safe margin of 106

years. This diversion was first manifested in a minor and short-lasting boosting of the growth of the world population.

The data are in disagreement with the Unified Growth Theory (Galor, 2005a; 2011), which erroneously claims stagnation and takeoffs from stagnation to growth. There was no stagnation but monotonically-increasing hyperbolic distribution. There were also no takeoffs from stagnation to growth around AD 1750 for developed regions and around AD 1900 for less-developed regions because there was no stagnation and because hyperbolic growth continued undisturbed. If there were such takeoffs in the respective regions they must have been too weak to change the growth of global population because the growth trajectory was remarkably stable during these alleged takeoffs. Furthermore, our analysis shows that the Industrial Revolution had no impact on the growth trajectory. Unified Growth Theory is yet again demonstrably contradicted by data.

With the absence of takeoffs in the growth of the population and with the earlier demonstrated absence of takeoffs in the growth of the GDP (Nielsen, 2016a), this analysis shows that there were no takeoffs in the income per capita (GDP/cap) distribution confirming our previous analysis based on the earlier compilation of Maddison's data (Maddison, 2001). Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

5. Western Europe

Growth of population in Western Europe is shown in Figures 5 and 6. Western Europe is represented by the total of 30 countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Sweden, Switzerland, United Kingdom, Greece, Portugal, Spain and by 14 small, but unspecified countries. Ireland is missing in this list because it was included only from 1921.

The straight line fitting the reciprocal values of data, shown in Figure 5, identifies uniquely hyperbolic distribution between AD 1000 and around 1915. Parameters describing hyperbolic growth in Western Europe are: $a = 7.542 \times 10^1$ and $k = 3.749 \times 10^{-2}$. The point of singularity is at $t = 2012$. From around 1915, the growth of population in Western Europe started to be diverted to a slower, but still fast-increasing, trajectory bypassing the singularity by a safe margin of 97 years. The size of the population in AD 1 is 89% larger than for the fitted hyperbolic distribution. This discrepancy is probably reflecting the maximum in the growth of the world population around that year (Nielsen, 2016c).

Figures 5 and 6 show that hyperbolic growth between AD 1000 and 1915 remained undisturbed. Industrial Revolution had absolutely no impact on changing the hyperbolic growth trajectory in the region where the effects of this revolution should be most prominent. There was no takeoff from stagnation to growth at the postulated time (Galor, 2008a; 2012a) because there was no stagnation in the growth of population. There was even no transition to a faster hyperbolic trajectory.

With the absence of the takeoff in the growth of the population in Western Europe and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a, 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

6. Eastern Europe

Results of analysis of the growth of population in Eastern Europe are summarized in Figures 7 and 8. Reciprocal values of data shown in Figure 7 identify uniquely hyperbolic distribution between AD 1000 and around 1935. From that year, the growth of population started to be diverted to a slower trajectory.

Hyperbolic parameters are: $a = 3.055 \times 10^2$ and $k = 1.525 \times 10^{-1}$. The point of singularity is at $t = 2003$. Figures 7 and 8 demonstrate that the Industrial Revolution had no impact on the trajectory of the growth of population in Eastern Europe and that there was no takeoff from stagnation to growth at the postulated time (Galor, 2008a; 2012a) because there was no stagnation but hyperbolic growth. There was even no takeoff to a faster hyperbolic growth. The size of the population in AD 1 was 45% higher than the calculated curve reflecting probably the maximum in the growth of the world population around that year (Nielsen, 2016c).

With the absence of the takeoff in the growth of population in Eastern Europe and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

7. Former USSR

The analysis of data for countries of the former USSR is presented in Figures 9 and 10. Reciprocal values shown in Figure 9 identify uniquely hyperbolic distribution between AD 1 and around 1920. Hyperbolic fit to the data is between AD 1 and 1870. Parameters fitting the data are: $a = 2.618 \times 10^2$ and $k = 1.333 \times 10^{-1}$. The singularity is at $t = 1965$. From around 1920, the growth of population in the former USSR started to be diverted to a slower trajectory, bypassing the singularity by around 45 years.

Figures 9 and 10 show that the Industrial Revolution had no impact on shaping the growth of human population in countries of the former USSR. There was also no takeoff from stagnation to growth around the postulated time Galor (2008a; 2012a) or around any other time because the growth was not stagnant but hyperbolic. There was even no transition to a faster hyperbolic trajectory but there was a transition to a slower, non-hyperbolic growth around 1920.

With the absence of the takeoff in the growth of the population in countries of the former USSR and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

8. Asia

Analysis of the growth of human population in Asia (including Japan) is summarised in Figures 11 and 12. Reciprocal values presented in Figure 11 identify uniquely hyperbolic distribution between AD 1000 and around 1920. Parameters describing this distribution are: $a = 1.068 \times 10^1$ and $k = 4.999 \times 10^{-3}$. The point of singularity is at $t = 2135$.

Asia is made primarily of less-developed countries (BBC, 2014; Pereira, 2011) and consequently, according to Galor (2008a; 2012a), the growth of human population in Asia should have been characterised by stagnation until around 1900, the year marking the alleged stunning escape from the Malthusian trap, the

supposed escape manifested by the postulated dramatic takeoff. (The population of Japan before AD 1900 was on average less than 4% of the total population of Asia.) The data and their analysis show that there was no stagnation, at least from AD 1000 and there was also no expected takeoff.

The data reveal a steadily increasing hyperbolic growth until around 1920. From around that year the growth of population was diverted to a faster trajectory. This boosting can be seen clearly in Figures 11 and 12 and it occurred close to the time of the postulated takeoff from stagnation to growth. However, it was not a transition from stagnation to growth but from hyperbolic growth to a slightly faster trajectory of a different kind. It is, therefore, not the takeoff postulated by Galor. Furthermore, it was only a temporary boosting, which is now returning to the original hyperbolic trajectory and, as indicated by the reciprocal values of data, this new trend is likely to be slower than the original trajectory.

With the absence of the postulated takeoff in the growth of population in Asia and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

9. Africa

Results of analysis of the growth of human population in 57 African countries are presented in Figures 13 and 14. Reciprocal values identify uniquely *two* hyperbolic trajectories: AD 1-1840 and AD 1840-1980. At first it was a slow hyperbolic growth characterised by parameters $a = 5.794 \times 10^1$ and $k = 2.473 \times 10^{-2}$ and by the singularity at $t = 2343$. Then, around 1840, this slow hyperbolic growth was replaced by a significantly faster hyperbolic growth characterised by parameters $a = 1.571 \times 10^2$ and $k = 7.834 \times 10^{-2}$ and by singularity at $t = 2006$. Defined by the parameter k , this new growth was 3.2 times faster than the earlier hyperbolic growth. From around 1980, this fast hyperbolic growth was diverted to a slower, non-hyperbolic trajectory, bypassing singularity by 26 years.

Africa is also made of less-developed countries (BBC, 2014; Pereira, 2011) so according to Galor (2008a; 2012a) it should have experienced stagnation until around 1900 followed by a clear takeoff around that year. These expectations are contradicted by data because (1) the growth of population was not stagnant but hyperbolic until around 1980 and (2) because there was no takeoff from stagnation to growth around 1900 or around any other time. In fact, around that time hyperbolic growth continued unaffected in contradiction of the wished-for interpretations.

The acceleration in the growth of human population in Africa occurred around 1840, but it was not a transition from stagnation to growth but from growth to growth. Even more precisely, it was a transition from hyperbolic growth to another hyperbolic growth.

Africa is the only region where the commencement of the rapid growth of population coincides with the Industrial Revolution but it also the region, which demonstrates that the usually-claimed effects of Industrial Revolution are contradicted by empirical evidence. According to the generally accepted interpretation, Industrial Revolution improved medical care and introduced many other beneficial effects, which were supposed to have caused population explosion. Data for Africa demonstrate that this wished-for mechanism does not work because the growth of population on this continent coincides with the rapidly-deteriorating living conditions of native populations brought about by the intensified

colonisation (Duignan & Gunn, 1973; McKay, Hill, Buckler, Ebrey, Beck, Crowston, & Wiesner-Hanks, 2012; Pakenham, 1992).

This fast growth of population in Africa, which commenced around the time when living conditions started to deteriorate rapidly, is easy to explain by noticing that the growth rate of population is *directly proportional to the level of deprivation* (Nielsen, 2013), the process, which is diametrically opposite to the usually claimed influence of the Industrial Revolution. It appears, therefore, that it is not the improved living conditions but the increased level of deprivation that have a stimulating effect on the growth of population.

With the absence of the takeoff around AD 1900 in Africa and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

10. Latin America

Results of analysis of population growth in Latin America are presented in Figures 15 and 16. Data for Latin America are difficult to analyse because there was a significant decline in the growth of population between AD 1500 and 1600 but they also appear to follow two distinctly different hyperbolic trajectories, which can be easily identified using the reciprocal values of data (see Figure 15). However, the identification of the first trajectory is not as clear as for Africa. The identification of the second hyperbolic trajectory is more convincing. Tentative conclusion is that the growth of population in Latin America was following a slow hyperbolic distribution between AD 1 and 1500 and a fast hyperbolic distribution between AD 1600 and around 1900.

The tentatively assigned slow hyperbolic growth between AD 1 and 1500 is characterised by parameters $a = 1.765 \times 10^2$ and $k = 8.242 \times 10^{-2}$. Its singularity is at $t = 2142$. The better determined fast hyperbolic growth between AD 1600 and 1900 is characterised by parameters $a = 6.561 \times 10^2$ and $k = 3.371 \times 10^{-1}$. Its singularity is at $t = 1947$. Defined by the parameter k , this growth was 4.1 times faster than the earlier hyperbolic growth. From around 1900, this fast hyperbolic growth started to be diverted to a slower trajectory bypassing the singularity by 47 years. The transition from the earlier apparent hyperbolic growth to a new and rapid hyperbolic growth, which occurred between around AD 1500 and 1600 appears to coincide with the commencement of the Spanish conquest (Bethell, 1984) and with the rapidly-deteriorating living conditions. The mechanism of this fast growth of population in Latin America appears to be the same as the mechanism of the fast growth in Africa, which commenced around AD 1840.

Latin America is also made of less-developed countries (BBC, 2014; Pereira, 2011) so again, according to Galor (2008a; 2012a), the growth of human population in this regions should have been stagnant until around 1900 and fast-increasing from around that year. This pattern of growth is contradicted by data. The data show a diametrically different pattern: (1) there is no convincing evidence of the existence of stagnation over the entire range of time between AD 1 and 1900 (there are no signs of Malthusian oscillations) but there is a sufficiently convincing evidence of hyperbolic growth particularly between AD 1600 and 1900; (2) there was no takeoff from stagnation to growth at any time; and (3) at the time of the postulated takeoff in 1900 the growth of population started to be diverted to a slower trajectory. The wished-for takeoff is replaced by a slower growth. However, even if we had a takeoff around that time it would have been a takeoff of a

different kind, not a takeoff from stagnation to growth as required by the Unified Growth Theory (Galor, 2005a; 2011) but a takeoff from growth to growth.

With the absence of the takeoff in the growth of population in Latin America and with the earlier demonstrated absence of the takeoff in the growth of the GDP (Nielsen, 2016a), this analysis shows that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory (Galor, 2005a; 2011) is contradicted by data, which were used but never analysed during the formulation of this theory.

11. Summary and conclusions

Results of mathematical analysis of the historical growth of human population are summarised in Table 1. The listed parameters, a and k , are for the fitted hyperbolic distributions.

This analysis demonstrates that the natural tendency for the historical growth of human population was to increase hyperbolically. In general, there is a remarkably good agreement between the data and the calculated hyperbolic distributions.

Unlike the more familiar exponential distributions, which are easier to understand because they show more readily a gradually increasing growth, hyperbolic distributions appear to be made of two or maybe even three components: a slow component, a fast component and perhaps even a transition component located between the apparent slow and fast components. The illusion is so strong that even the most experienced researchers can be deceived particularly if they have no access to good sets of data, which was in the past. Now, however, excellent data are available (Maddison, 2001; 2010) and we can use them to check the earlier interpretations of economic growth and of the growth of human population.

Table 1. Summary of the mathematical analysis or the historical growth of population

Region/Countries	a	k	Hyperbolic Range	Singularity	Proximity	Take off
World	7.739×10^0	3.765×10^{-3}	1000 – 1950	2056	106	X
Western Europe	7.542×10^1	3.749×10^{-2}	1000 – 1915	2012	97	X
Eastern Europe	3.055×10^2	1.525×10^{-1}	1000 – 1935	2003	68	X
Former USSR	2.618×10^2	1.333×10^{-1}	1 – 1920	1965	45	X
Asia	1.068×10^1	4.999×10^{-3}	1000 – 1920	2135	215	X
Africa	5.794×10^1	2.473×10^{-2}	1 – 1840 1840 – 1980	2343 2006	26	X
Latin America	1.765×10^2	8.242×10^{-2}	1 – 1500 1600 – 1900	2142 1947	47	X
	6.561×10^2	3.371×10^{-1}				

Notes: a and k – Hyperbolic growth parameters [see eqn (1)]. *Hyperbolic Range* - The empirically-confirmed range of time when the growth of population can be described using hyperbolic distributions. *Singularity* - The time of the escape to infinity for a given hyperbolic distribution. *Proximity* - Proximity (in years) of the singularity at the time when the growth of population departed from the hyperbolic growth to a new trajectory. *X* - No takeoff from stagnation to growth. Takeoffs claimed by the Unified Growth Theory (Galor, 2005a, 2008a, 2011, 2012a) did not happen because there was no stagnation in the growth of population. The growth was monotonically hyperbolic.

The postulate of the existence of the epoch of Malthusian stagnation is suggested by a slow growth over a long time but this slow growth is just a part of the hyperbolic growth, which can be convincingly identified using reciprocal values. Hyperbolic distributions create also the illusion of a sudden takeoff but this feature is also a part of hyperbolic growth.

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Hyperbolic growth is slow over a long time and fast over a short time but the slow and fast growth are the integral features of the same *monotonically increasing* distribution, which is easier to understand by using the reciprocal values of the growing entity (Nielsen, 2014). In such displays, the illusion of distinctly different components disappears because hyperbolic growth is then represented by a decreasing straight line, which is easy to understand. It then becomes obvious that hyperbolic distribution cannot be divided into distinctly different sections governed by different mechanism because it makes no sense to divide a straight line into arbitrarily chosen sections and claim different mechanism for such arbitrarily-selected section. It is then also clear that it is impossible to determine the transition from a slow to fast growth. Which point on a straight line should we select to identify such a transition? The transition does not happen at any specific time but gradually over the whole range of time.

Our analysis shows that the Industrial Revolution had generally no impact on the growth of human population. The only boosting of growth, which coincided with the Industrial Revolution was in Africa but this boosting appears to have not been caused by the usually assumed beneficial effects of the Industrial Revolution but by the rapidly deteriorating living conditions associated with the colonisation of Africa. Our analysis also shows that the postulated takeoffs from stagnation to growth (Galor, 2005; 2008a; 2011; 2012a) never happened because there was no stagnation in the growth of population. We have shown earlier (Nielsen, 2016a) that there were no takeoffs in the growth of the GDP, global or regional. The demonstrated now absence of takeoffs in the growth of population shows that the claimed by Galor takeoffs in the income per capita (GDP/cap) did not exist.

Galor describes the imaginary and non-existing features, which have nothing to do with the economic growth or with the growth of human population, features which were conjured from such habitually distorted displays as shown in Figure 1, interpretations based on impressions, which were never checked by the scientific analysis of data. They describe a world of fiction. All his explanations of the mechanism of economic growth based on these and other imaginary features are not only irrelevant but also misleading.

Galor's Unified Growth Theory is fundamentally incorrect and is repeatedly contradicted by data (Nielsen, 2014; 2015a; 2016a; 2016b; 2016d), ironically by the same data, which were used but never analysed during the formulation of this theory. The evidence contradicting the fundamental postulates of the Unified Growth Theory is overwhelming and further evidence will be presented in forthcoming publications. This evidence questions not only the fundamental postulates of the Unified Growth Theory but also many similar postulates used traditionally in economic and demographic research, postulates which are based largely on impressions and conjectures but postulates, which are repeatedly contradicted by the analysis of Maddison's data (Maddison, 2001; 2010) as well as by other related research (Kapitza, 2006; Kremer, 1993; Podlazov, 2002; Shklovskii, 1962; 2002; von Foerster, Mora & Amiot, 1960; von Hoerner, 1975; see also Nielsen, 2016c; 2016e and references therein).

In science, just one contradicting evidence is sufficient to show that contradicted postulates need to be closely examined and revised. Unified Growth Theory is scientifically unacceptable and so are also many traditional interpretations of the historical economic growth and of the growth of human population.

Data and their analysis suggest new lines of research. There is no need to waste time to discuss and explain the mechanism of stagnation and takeoffs from stagnation to growth because these features are contradicted by data. What needs to be explained is why the historical economic growth and the growth of human

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population were hyperbolic and why relatively recently they were diverted to slower but still fast-increasing trajectories. There is also a need to find out how to control these fast-increasing trajectories.

Unified Growth Theory is not only spurious but also dangerously misleading. It claims erroneously that after a long epoch of stagnation in the economic growth we have now entered a sustained-growth regime. This concept suggests a prosperous and secure future. However, mathematical analysis of data shows that the past economic growth was stable and sustainable but now it increases alarmingly fast (Nielsen, 2015b; 2016a). The false sense of security is replaced by the realisation of the urgent need to control and regulate economic growth and by the generally known need to control the growth of population.

Appendix

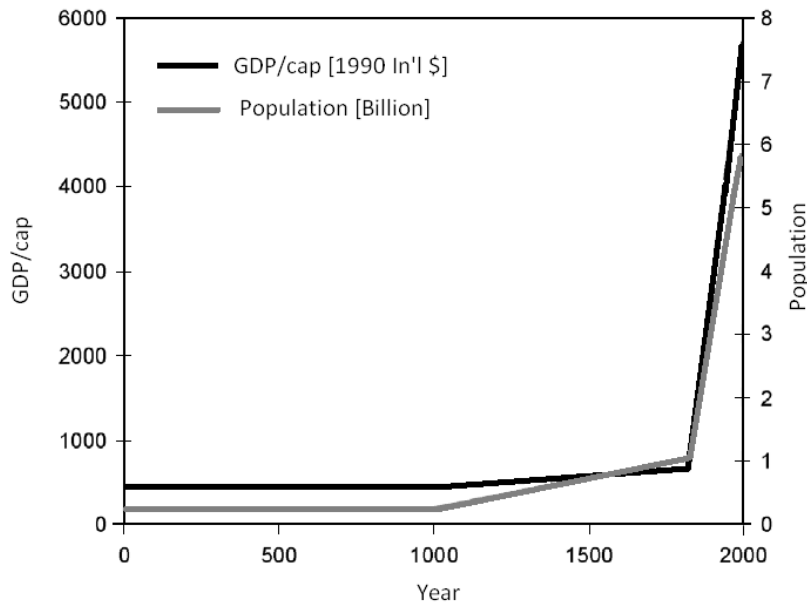


Figure 1. Example of the ubiquitous, grossly-distorted and self-misleading diagrams used to create the Unified Growth Theory (Galor, 2005a, 2011). Maddison's data (Maddison, 2001) were used during the formulation of this theory but they were never analysed. Such state-of-the-art was used to construct a system of scientifically-unsupported concepts, interpretations and explanations.

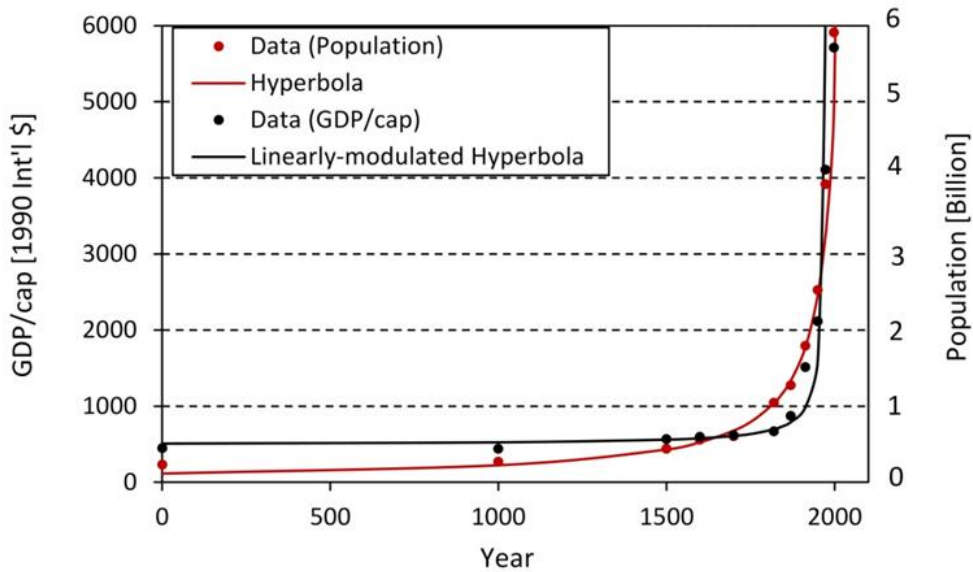


Figure 2. The same data (Maddison, 2001) as used in Figure 1 but now displayed accurately and analysed. They follow monotonically-increasing distributions, which cannot be divided into distinctively-different components (Nielsen, 2014, 2015a).

World Population

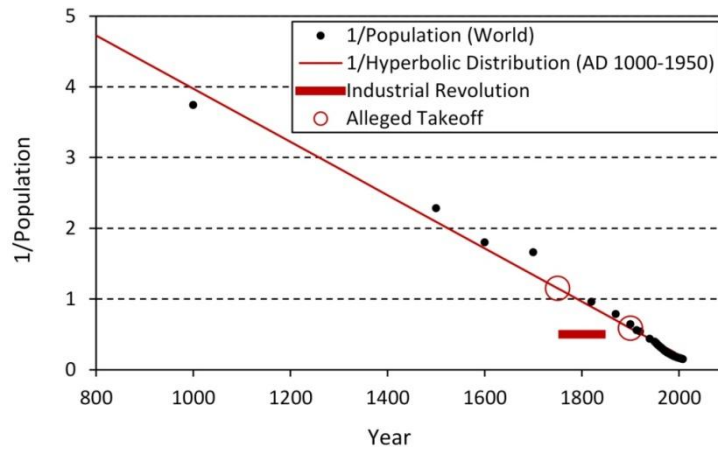


Figure 3. Reciprocal values of the world population data (Maddison, 2010) identify uniquely hyperbolic distribution between AD 1000 and around 1950 because they follow a decreasing straight line. From around 1950, the growth of population started to be diverted to a new trajectory. Industrial Revolution had no impact on changing the growth trajectory. There were also no takeoffs from stagnation to growth around the postulated times for developed and less-developed regions (Galor, 2008a, 2012a). This analysis and the absence of takeoffs in the corresponding GDP distribution (Nielsen, 2016a) show that there were no takeoffs in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

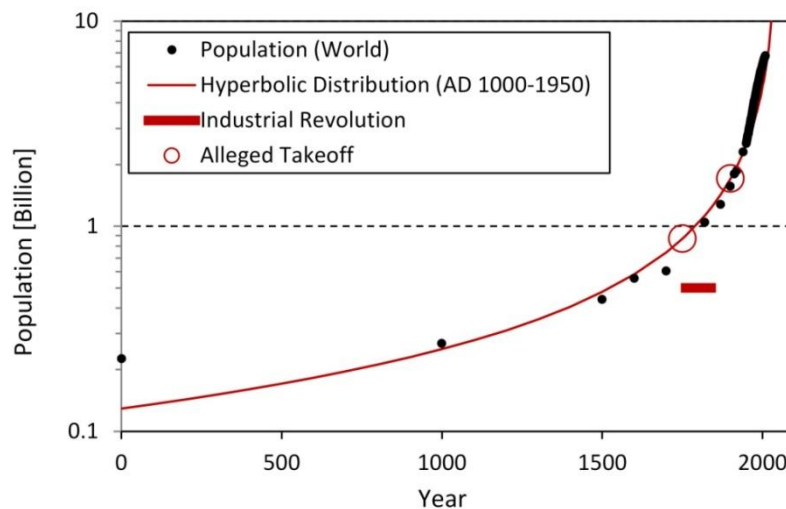


Figure 4. Growth of the world population. Data of Maddison (2010) are compared with hyperbolic distribution. The point at AD 1 is 75% higher than the fitted curve because there was a maximum in the growth of the world population around that time (Nielsen, 2016c). Industrial Revolution had no impact on the growth of population. There were no takeoffs from stagnation to growth around the postulated time (Galor, 2008a, 2012a) for developed and less-developed regions. This analysis and the absence of takeoffs in the corresponding GDP distribution (Nielsen, 2016a) show that there were no takeoffs in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Western Europe

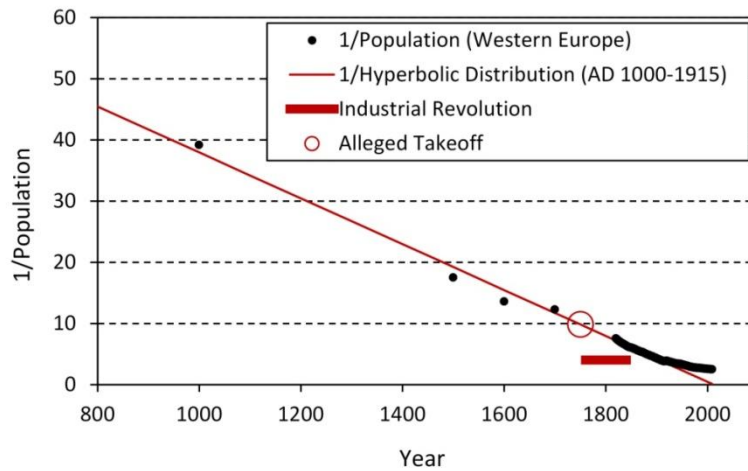


Figure 5. Reciprocal values of population data for Western Europe (Maddison, 2010) identify uniquely hyperbolic distribution between AD 1000 and around 1915 because they follow a decreasing straight line. From around 1915, the growth of population started to be diverted to a slower trajectory. Industrial Revolution had no impact on changing the growth trajectory in the region where its influence should have been most pronounced. There was also no takeoff from stagnation to growth around the postulated time (Galor, 2008a, 2012a). This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

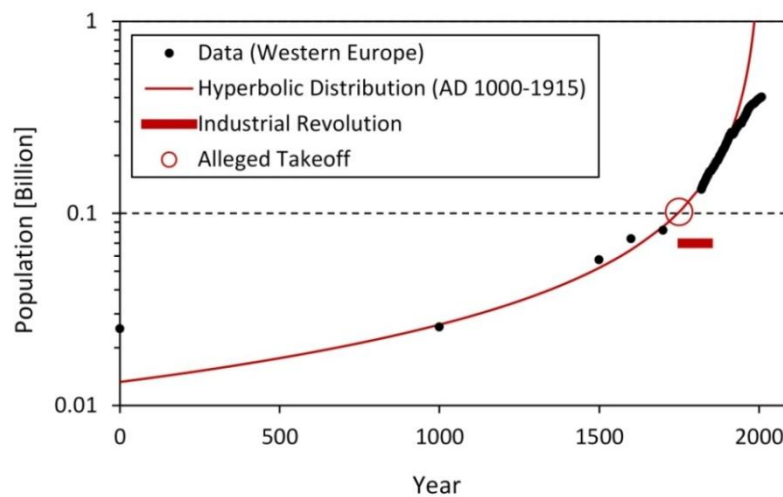


Figure 6. Growth of human population in Western Europe. Data of Maddison (2010) are compared with hyperbolic distribution. The point at AD 1 is 89% higher than the fitted curve. This discrepancy might be reflecting the maximum in the growth of the world population (Nielsen, 2016c). Industrial Revolution had no impact on the growth of population in Western Europe where the effects of this revolution should have been most prominent. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a, 2012a). This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Eastern Europe

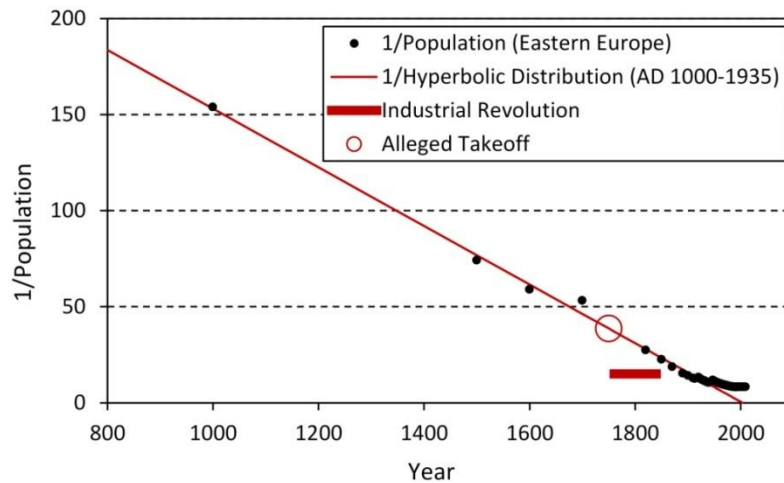


Figure 7. Reciprocal values of population data for Eastern Europe (Maddison, 2010) identify uniquely hyperbolic distribution between AD 1000 and around 1935 because they follow a decreasing straight line. From around 1935, hyperbolic growth started to be diverted to a slower trajectory. Industrial Revolution had no impact on changing the growth trajectory in Eastern Europe. There was also no takeoff from stagnation to growth around the postulated time (Galor, 2008a, 2012a). This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

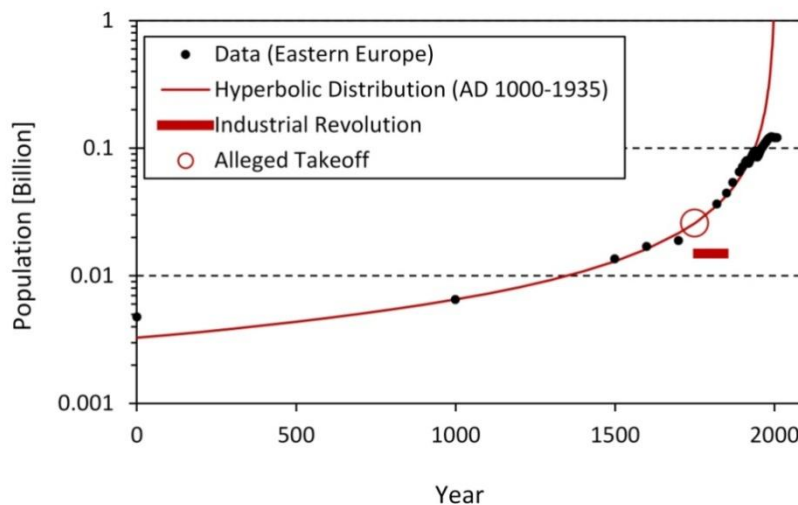


Figure 8. Growth of human population in Eastern Europe. Data of Maddison (2010) are compared with hyperbolic distribution. The point at AD 1 is 45% higher than the fitted curve. This discrepancy might be reflecting the maximum in the growth of the world population (Nielsen, 2016c) around that time. Industrial Revolution had no impact on the growth of population in Eastern Europe. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a). This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Former USSR

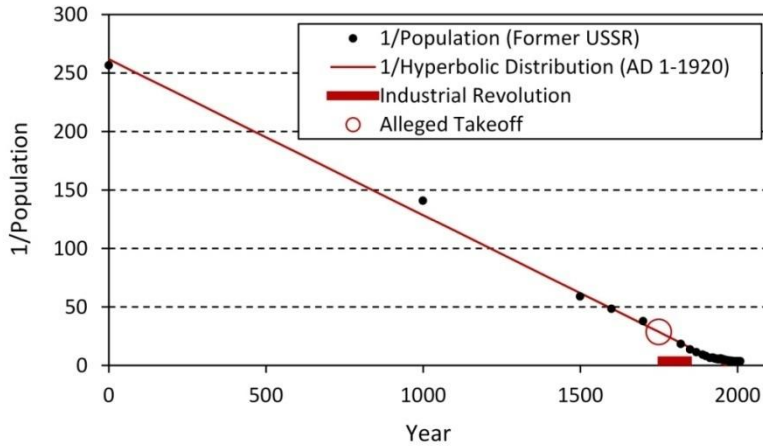


Figure 9. Reciprocal values of population data for the former USSR (Maddison, 2010) identify uniquely hyperbolic distribution between AD 1 and 1920 because they follow closely the decreasing straight line. From around 1920 the growth started to be diverted to a slower trajectory. Industrial Revolution had no impact on changing the growth trajectory. There was also no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) or around any other time because there was no stagnation. There was even no transition to a faster hyperbolic growth. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

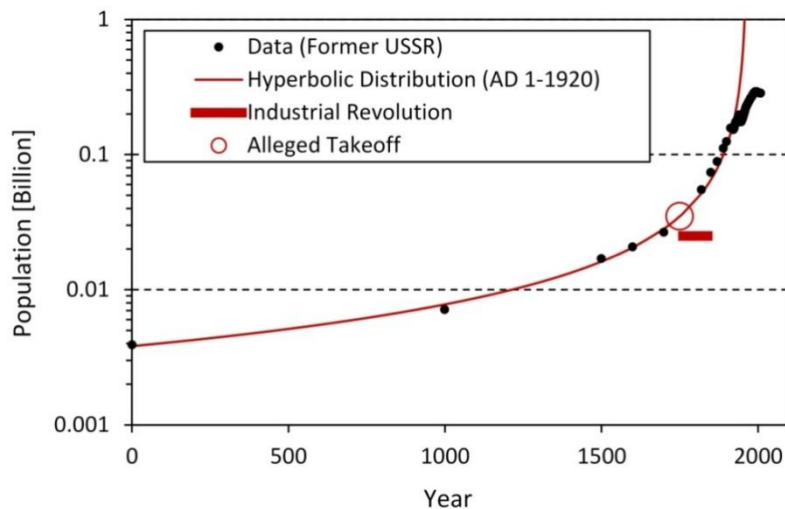


Figure 10. Growth of human population in countries of the former USSR. Data of Maddison (2010) are compared with hyperbolic distribution. Industrial Revolution had no impact on the growth of population. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) or around any other time because there was no stagnation. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Asia (including Japan)

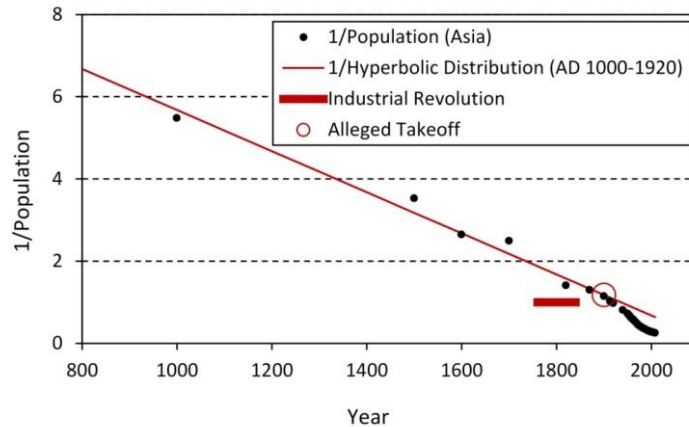


Figure 11. Reciprocal values of population data for Asia (Maddison, 2010) identify uniquely hyperbolic distribution between AD 1 and 1920 because they follow closely the decreasing straight line. From around 1920, the growth started to be diverted to a temporary faster trajectory. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) because there was no stagnation. The temporary boosting around 1920 appears to be a part of the commonly observed transition from the historical hyperbolic growth to a slower trajectory. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

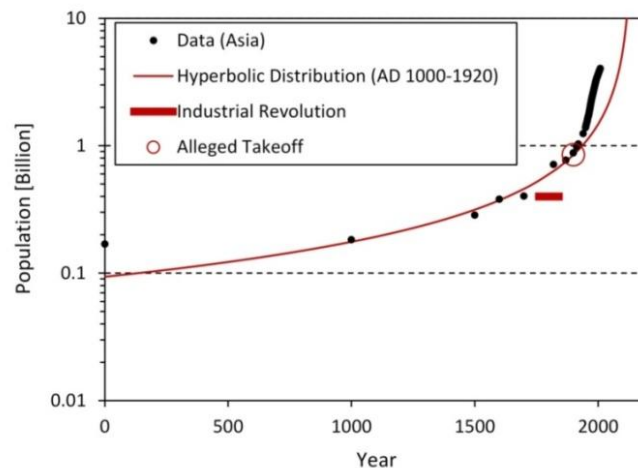


Figure 12. Growth of human population in Asia. Data of Maddison (2010) are compared with the hyperbolic distribution. There was no stagnation but a hyperbolic growth between at least AD 1000 and 1920. The size of the population at AD 1 is 80% higher than the fitted hyperbolic distribution, reflecting probably the maximum in the growth of the world population around that year (Nielsen, 2016c). There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) because there was no stagnation before the temporary boosting from around 1920. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Africa

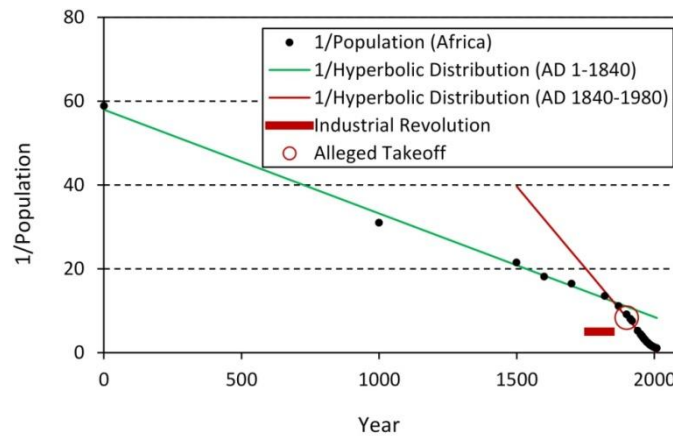


Figure 13. Reciprocal values of population data for Africa (Maddison, 2010) identify uniquely two hyperbolic distributions: AD 1-1840 and AD 1840-1980 because they follow closely the decreasing straight lines. From around 1980 the growth started to be diverted to a slower trajectory. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) because there was no stagnation. However, there was a transition around AD 1840 from a slow to a fast hyperbolic trajectory. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

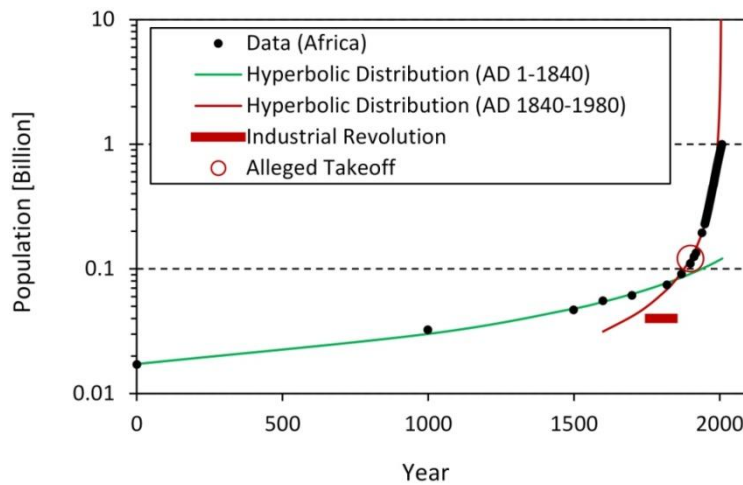


Figure 14. Growth of human population in Africa. Data of Maddison (2010) are compared with two hyperbolic distributions, AD 1-1840 and AD 1840-1980. There was no stagnation but a hyperbolic growth. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) because there was no stagnation. The fast hyperbolic growth, continued undisturbed until 1980 when it started to be diverted to a slower trajectory. Around 1840, there was a transition from a slow to a fast hyperbolic trajectory. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

Latin America

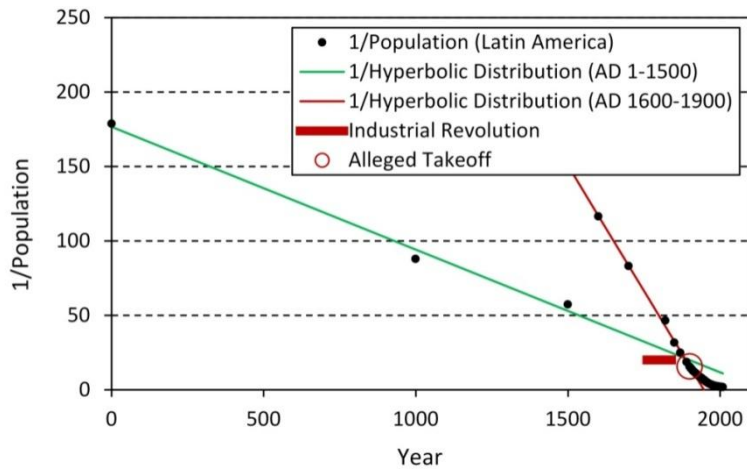


Figure 15. Reciprocal values of population data for Latin America (Maddison, 2010) identify two hyperbolic distributions: AD 1-1500 and AD 1600-1900 because they follow closely the decreasing straight lines. From around 1900 the growth started to be diverted to a slower trajectory. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) but there was a transition around the postulated takeoff to a slower trajectory. Data replace Galor's takeoff by a transition to a slower trajectory. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

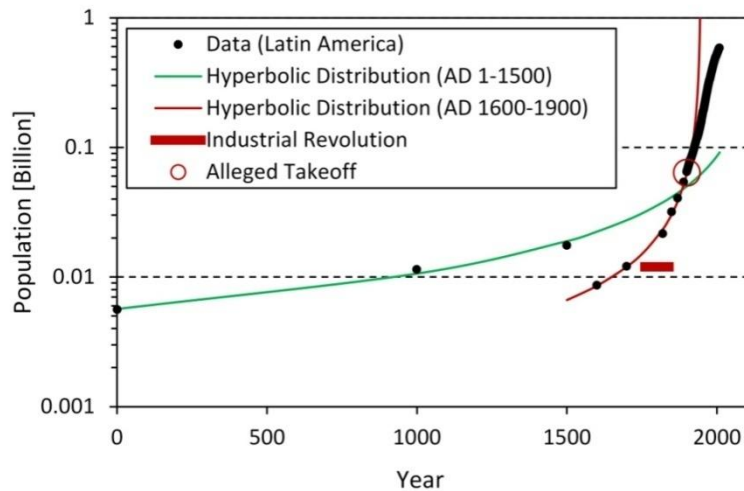


Figure 16. Growth of human population in Latin America. Data of Maddison (2010) are compared with two hyperbolic distributions, AD 1-1500 and AD 1600-1900. There was no stagnation but a hyperbolic growth. There was no takeoff from stagnation to growth around the postulated time (Galor, 2008a; 2012a) because there was no stagnation. The fast hyperbolic growth continued undisturbed until 1900 when it started to be diverted to a slower trajectory. Data replace Galor's takeoff by a transition to a slower trajectory. This analysis and the absence of the takeoff in the corresponding GDP distribution (Nielsen, 2016a) show that there was no takeoff in the income per capita (GDP/cap) distribution. Unified Growth Theory is contradicted yet again by the same data which were used but not analysed during the formulation of this theory.

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