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The Dichotomy of Malthusian Positive Checks: Destruction and even more Intensified Regeneration

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Abstract. Impacts of Malthusian positive checks are investigated using data compiled by the United Nations Development Program. We show how the intensity of Malthusian positive checks are correlated with indicators describing the standard of living such as ecological footprint, income per capita, severe poverty, access to pure water and access to sanitation facilities. We then show that mortality increases exponentially with the intensity of Malthusian positive checks (adult mortality, under-five mortality, maternal mortality and deaths by polluted water). However, total fertility rate also increases exponentially. One of the important results of our analysis is that the growth rate and the rate of natural increase are directly proportional to the intensity of Malthusian positive checks. The regenerating impacts triggered by Malthusian positive checks do not just keep the growth undisturbed – they stimulate growth and make it even faster. Using data for Africa, we also show that while the death rate increases with the intensity of hunger, total fertility rate, birth rate and the rate of natural increase also increase. Records from China also show that Malthusian positive checks of wars and famines triggered the intensified growth of population. Thus, contrary to the generally promoted interpretations, hunger and famines do not necessarily suppress the growth of population. Similar patterns of stress-induced growth are also observed in nature. This study is closely related to the problem of controlling the growth of human population.
Keywords. Malthusian positive checks, Population growth, Income per capita, Birth and death rates, Total fertility rate, Growth rate, Rate of natural increase
JEL. A12, C12, Y80.

1. Introduction

Maltus (1798) is well known for a dubious reason of having his name associated with the erroneous concept of stagnation expressed in such phrases as Malthusian stagnation, Malthusian regime, epoch of Malthusian stagnation, Malthusian trap and escape from Malthusian trap, the concept he never proposed or advocated, the concept based on impressions, on a good dose of fantasy and on the suitable manipulation of data (Ashraf, 2009; Galor, 2005a; 2005b; 2007; 2008a; 2008b; 2008c; 2010; 2011; 2012a; 2012b; 2012c; Galor & Moav, 2002; Snowdon & Galor, 2008). The concept of stagnation and all other related concepts have been repeatedly and convincingly contradicted by data and by their mathematical analyses (Biraben, 1980; Clark,1968; Cook,1960; Durand, 1974; Gallant, 1990; Haub, 1995; Kapitza, 2006; Kremer, 1993; Lehmeyer, 2004; Livi-Bacci, 1997; Maddison, 2001; 2010; Mauritius, 2015; McEvedy & Jones, 1978; Nielsen, 2013a; 2013b; 2013c; 2014; 2015; 2016a;

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2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; Podlazov, 2002; Shklovskii, 1962; 2002; Statistics Mauritius, 2014; Statistics Sweden, 1999; Taeuber & Taeuber, 1949; Thomlinson, 1975; Trager, 1994; United Nations, 1973; 1999; 2013; von Hoerner, 1975; von Foerster, Mora & Amiot, 1960; Wrigley & Schofield, 1981).

Malthus (1798) proposed three fundamental mechanisms contributing to the growth of human population: (1) the devastating effects of positive checks, (2) the regenerating effects of positive checks and (3) the effects of preventive checks. He did not explain the mechanism of growth of population. He only claimed that "Population, when unchecked, increases in a geometrical ratio" (Malthus, 1978, p. 4). Now we know that this is not true. Population, when unchecked does not increase in a geometrical ratio (exponentially) but hyperbolically (Kapitza, 2006; Kremer, 1993; Nielsen, 2016b, 2016d; Podlazov, 2002; Shklovskii, 1962, 2002; von Hoerner, 1975, von Foerster, Mora & Amiot, 1960).

Malthus carried out an important pioneering work but it was for the future generations of researchers to explore these three proposed contributing mechanisms and to understand their impacts, if any, on the growth of population. Malthus did not have sufficient data to carry out such research. He described lethal effects of demographic catastrophes but he never claimed explicitly that they would create a lasting stagnation in the growth of human population, let alone that they would produce the epoch of stagnation as it is now erroneously claimed (Galor, 2005a, 2011). Indeed, his claim that population if unchecked increases exponentially seems to suggest that he did not imagine prolonged or lasting effects of such positive checks.

Now we know that the growth of the world population, for instance, might have been checked only once in the past 12,000 years by the unusual convergence of no fewer than *five* major demographic catastrophes, which introduced only a *minor disturbance* between AD 1200 and 1400 (Nielsen, 2016d). There is also no convincing evidence of the frequently occurring devastating effects of Malthusian positive checks in the growth of regional populations (Nielsen, 2016b). These surprising results could be perhaps explained in two ways: (1) that the relative impacts of demographic catastrophes were generally too small and (2) that the devastating effects of positive checks were to a certain degree compensated by their regenerating effects, which Malthus mentions in his book.

The aim of the current publication is to continue the work of Malthus and to investigate impacts of positive checks, the work Malthus could not do because he did not have relevant data. He described the devastating effects of positive checks but he also did not fail to notice and record their positive effects in stimulating growth.

We shall start from where Malthus was forced to stop and we shall investigate how the effects of positive checks are reflected in the growth of human population. We shall assume that the intensity of Malthusian positive checks can be measured by the level of deprivation. We shall first define this indicator. We shall then see how this indicator is reflected in the standard of living. Using this indicator, we shall then see how Malthusian positive checks are reflected in the destructive effects such as the increased death rates. We shall then investigate the other side of these positive checks and demonstrate how they are reflected in the process of regeneration, such as in the increased rate of natural increase, the increased growth rate and the increased total fertility rate. This study will allow us to extend the work of Malthus, which he published around 200 years ago, and to understand better the effects of his positive checks, the effects outlined only briefly in his book.

2. Measuring the intensity of Malthusian positive checks

Effects of Malthusian positive checks can be studied conveniently using the data compiled by the United Nations Development Program (UNDP, 2011). These data are linked with the three-dimensional Human Development Index (HDI) (UNDP, 2010), which is defined using the levels of health, education and income. Human Development Index varies between 0 and 1 and measures the level of human development or the level of prosperity. The HDI close to 1 is for prosperous countries.

We could use this index to describe *indirectly* the intensity of Malthusian positive checks but then in order to understand the studied correlations, which we are going to present, and to study the effects Malthusian positive checks, we would have to translate mentally the HDI into the levels of deprivation. In order to link the UNDP data *directly* to the level of deprivation and thus to the intensity of Malthusian positive checks, it is better to introduce just a slight modification of the HDI and define the Level of Deprivation Index (LDI) as:

$$LDI \equiv 1 - HDI \tag{1}$$

This index varies from around 0 (for the low level of deprivation) to around 1 (for the high level of deprivation). At the high end of the spectrum, this index is linked directly or indirectly with such conditions as poor health care, low income, severe poverty, inadequate access to sanitation facilities, inadequate access to pure water, hunger, inadequate housing, poor education, devastating effects of wars and military conflicts, high incidents of infectious diseases and all other conditions, which are usually identified as representing the intensity of Malthusian positive checks. As the level of deprivation decreases, the intensity of Malthusian positive checks also decreases.

It should be noted that for Malthus positive checks were not necessarily represented by the usually claimed great calamities such as wars, famines and pestilence. Furthermore, for him, positive checks did not have to apply to the whole country but to certain groups of people within a given country or even to individual families.

> Notwithstanding, then, the institution of the poor laws in England, I think it will be allowed that considering the state of the *lower classes* altogether, both in the towns and in the country, the *distresses* which they suffer from the want of *proper and sufficient food*, from *hard labour* and *unwholesome habitations*, must operate as a *constant check* to incipient population. (Malthus, 1798, p.31. Italics added.).
>
> Labour would be ill paid. Men would offer to work for a bare subsistence, and *the rearing offamilies would be checked by sickness and misery* (Malthus, 1798, p.64. Italics added.).

In all mathematical formulae and diagrams presented in this study, x is reserved exclusively for the LDI, which will be always used as an independent variable, while y will be used for any relevant dependent variable. It should be also noted that while the derived formulae can have a general application, the exact values of the constants apply only to the data published by UNDP (2011).

We shall first examine how the level of deprivation, i.e. how the intensity of Malthusian positive checks, is reflected in the standard of living represented by such indicators as the ecological footprint (EF), income per capita, the intensity of severe poverty, access to clean water and access to sanitation facilities. We shall then examine the devastating effects of Malthusian positive checks as reflected in the increased morality. Finally, we shall examine the regenerating effects by

showing how growth-promoting indicators depend on the intensity of Malthusian positive checks.

3. Malthusian positive checks reflected in the standard of living

We shall now present three examples showing how the intensity of Malthusian positive checks as described by the Level Deprivation Index are correlated with the standard of living.

3.1. Malthusian positive checks reflected in the ecological footprint (EF)

Ecological footprint (EF) measures the level of consumption of natural resources and the level of the associated damage to the environment (Ewing, et al., 2010). The footprint is expressed in global hectares per person [gha/cap] of the biologically productive surface area: crops, grazing, fishing, forests for timber and firewood, forests for carbon dioxide absorption and land for human habitat.

The dependence of the ecological footprint (EF) on the Level of Deprivation Index (LDI), based on the UDDP data (UNDP, 2011), is shown in Table 1. Small ecological footprint is associated with a small consumption of natural resources and with a high intensity of Malthusian positive checks as reflected in the Level of Development Index (LDI). These data show that only a small fraction of human population is responsible for the excessively large ecological footprint.

Table 1. *The average Level of Deprivation Index (LDI) and the average ecological footprint (EF), expressed in gha/cap, for various levels of human development, based on the UNDP data (UNDP, 2011).*

Level of development	LDI	EF [gha/cap]	Population [Million]
Very high human development	0.111	5.8	1,130
High human development	0.259	2.5	973
Medium human development	0.370	1.7	3,546
Low human development	0.544	1.2	1,260

The average global ecological footprint in 2011 calculated using the UNDP data (UNDP, 2011) was 3 gha/cap. According to the data shown in Table 1, ecological footprint was higher than this average value for 16.5% of the world population. For this small groups of people, the average intensity of Malthusian positive checks was low (LDI = 0.111). In contrast, for 18.4% of global population, the intensity of Malthusian positive checks was approximately five times higher (LDI = 0.544). The dependence of the ecological footprint on the level of deprivation is shown in Figure 1. Each dot in this diagram (and in all other diagrams presented in this publication) represents one of the 187 countries listed in the UNDP compilation (UNDP, 2011).

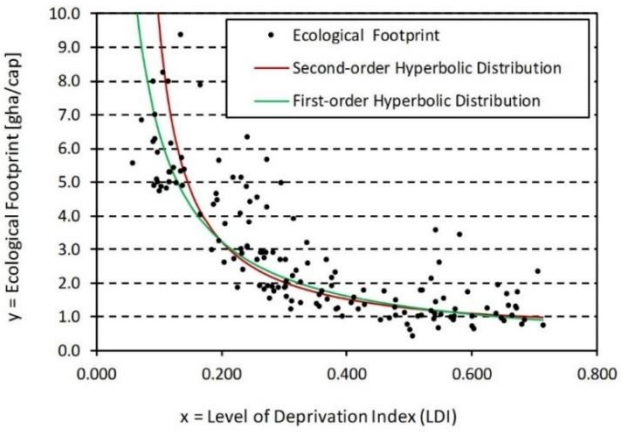

Figure 1. *Correlation between the intensity of Malthusian positive checks as measured by the LDI and the ecological footprint (EF). The data are from the United Nations Development Program (UNDP, 2011). They are compared with two best fits using hyperbolic distributions.*

The best fit to the data presented in Figure 1 is obtained by using the second-order hyperbolic distribution:

$$y = (a_0 + a_1 x + a_2 x^2)^{-1} \ , \tag{2}$$

where x is the LDI and y is the ecological footprint. For this set of data (UNDP. 2011), $a_0 = 0.126$, $a_1 = 4.406$ and $a_2 = -1.139$.

However, a satisfactory fit can be also obtained using a much simpler, first-order, hyperbolic distribution

$$y = ax^{-1}, \tag{3}$$

where $a = 0.646$.

For the large values of the LDI, ecological footprint increases slowly with the decreasing level of deprivation. Thus, in the extreme case, for countries characterised by the high values of the LDI, i.e. by the high intensity of Malthusian positive checks, a large reduction in the level of deprivation, and thus in the intensity of Malthusian positive checks can be achieved by only a relatively small increase in the ecological footprint.

We shall show later how the intensity of growth of population increases with the intensity of the LDI, i.e. with the intensity of Malthusian positive checks. Figure 1 suggests that large reductions in the intensity of growth of human population could be achieved by improving living conditions of poor countries through a relatively small increase in their ecological footprint.

In contrast, as we can see from the correlation presented in Figure 1, a large increase in the ecological footprint of rich countries (characterised by the low LDI values) results in only marginal improvement in their standard of living. Their standard of living is already so high that to improve it by only a small degree requires enormous increase in their consumption of natural resources, which is not only unfair for poor countries but also imprudent because a better distribution of wealth could contribute significantly to reducing the growth of human population and to the global security.

3.2. Malthusian positive checks reflected in the income per capita

The dependence of the Gross Domestic Product per person (GDP/cap) on the level of deprivation is shown if Figure 2.

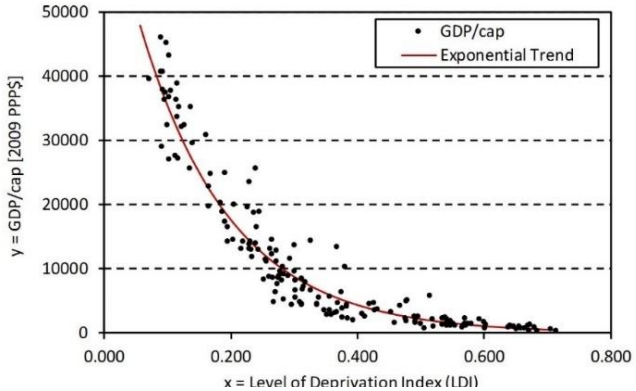

Figure 2. *Exponential dependence of the Gross Domestic Product per person (GDP/cap) on the Level of Deprivation Index (LDI). The GDP is in the purchasing power parity of 2009 international dollars*

The GDP/cap decreases exponentially with the increasing level of deprivation, i.e. with the intensity of Malthusian positive checks. The range of the GDP/cap is between $319 for the Demographic Republic of Congo and $91,379 for Qatar, with the US ($45,989) and Switzerland ($45,224) being located in the middle.

The best fit to the data is obtained using exponential function,

$$y = be^{rx}, \tag{4}$$

where x is the LDI and y is the GDP/cap. For these particular set of data (UNDP, 2011), b = $71,144 and $r = -6.97$.

Results presented in Figure 2 lead to the same conclusions as results shown in Figure1. At the far end of the LDI scale, a small increase in the GDP/cap by only around $4,000, on average, would advance countries from the low to medium level of human development. In contrast, an increase by around $20,000 would be needed to advance countries from high to very high level of human development. We can also look at it by comparing the increase in the GDP/cap needed to decrease the LDI by the same interval. For instance, to decrease the LDI from 0.500 to 0.400 one would need to increase, on average, the GDP/cap by only $2,000. In contrast, to decrease the LDI from 0.300 to 0.200 one would need to increase the GDP/cap by around $9,000.

3.2. Malthusian positive checks reflected in the severe poverty and in other related indicators

The dependence of the fraction of the population living in severe poverty on the intensity of Malthusian positive checks is shown in Figure 3.

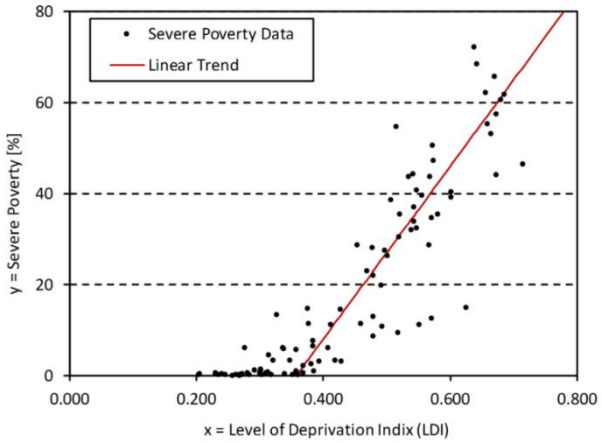

Figure 3. *The fraction of population living in severe poverty (y) represented as a function of the LDI (x), i.e. as a function of the intensity of the Malthusian positive checks.*

It is essential to notice two important features of the correlation presented in Figure 3. *First*, the correlation is linear. *Second*, the correlation is characterised by a certain threshold below which the fraction of the population living in severe poverty is on average zero. The intensity of Malthusian positive checks decreases linearly with the level of poverty. However, when the fraction of the population living in severe poverty reaches its zero value, the intensity of Malthusian positive checks reaches a certain threshold level. Any further decrease in the intensity of Malthusian positive checks is no longer correlated with the level of severe poverty, but it will continue to be correlated with the ecological footprint and with income per capita.

This linear correlation indicates that severe poverty can be reduced even to zero without trying to reduce the intensity of Malthusian positive checks to zero. The reduction in the level of severe poverty will come first. After that, there could be other improvements, which would be reflected in other parameters describing the standard of living.

Similar step-wise linear correlations apply also to the fraction of the population living below the poverty line and to the Multidimensional Poverty Index (MPI). The same type of correlations applies also to the size of the population with no access to clean water and to the size of the population with no access to sanitation facilities. All these data can be fitted using a simple mathematical expression:

$$y = m(x - n)\,,\; y \geq 0\,, \tag{5}$$

where n is a threshold below which $y \approx 0$.

For the data presented in the UNDP report (UNDP, 2011) and for the fraction of the population living in severe poverty, m = 190 and n = 0.358. In terms of the ecological footprint and of the GDP/cap, this threshold corresponds to 1.7 gha/cap and $5,858/cap, respectively. Above these thresholds, the fraction of the population living in severe poverty could be expected to be on average negligibly small.

For all indicators, mentioned earlier and characterised by such linear correlations, and for the data listed in the UNDP report (UNDP, 2011) the respective thresholds in the LDI vary between 0.293 and 0.371. In terms of the EF and the GDP/cap, they vary between 1.6 and 2.1 gha/cap for the EF, and between $5,350 and $9,218 for the GDP/cap. These figures suggest that a moderate improvement in the living conditions of poor countries could have an enormous impact on reducing the level of poverty and on improving access to clean water and

to sanitation facilities. We shall see later that the added benefit of improving the standard of living in poor countries could be a significant reduction in the growth of population.

4. The lethal impacts of Malthusian positive checks

We can now take the next step and try to understand the destructive effects of Malthusian positive checks. An example of the dependence of mortality on the intensity of Malthusian positive checks is shown in Figure 4 for adult mortality.

The effect is quite remarkable: mortality increases exponentially. We can analyse other relevant data (UNDP, 2011) and we shall get consistently similar results. Such exponential increase applies to deaths due to polluted water, maternal mortality and under-five mortality. It would appear that the exponential dependence of mortality on the intensity of Malthusian positive checks could be expected to apply also to other forms of mortality.

Malthus did not study how mortality depends on the intensity of positive checks. He only pointed out that positive checks can be linked with the increased mortality. Now we know not only that mortality increases with the intensity of positive checks but also *how* it increases – it increases exponentially.

The exponential distribution shown in Figure 4 is described by the eqn (4) but now with the positive parameter r. For the set of data listed by UNDP (2011), b = 124.83 and r = 2.925. Adult mortality is on average 66% higher in countries characterised by low human development than in countries characterised by medium human development, nearly 130% higher than in countries characterised by high human development and 255% higher than in countries characterised by very high human development.

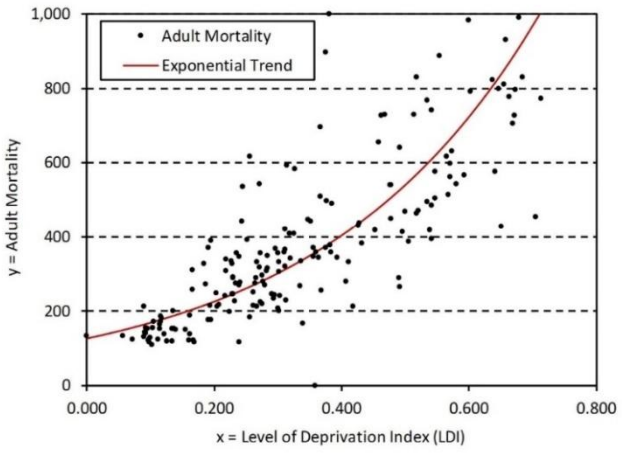

Figure 4. *Exponential dependence of adult mortality (per 1000 adult population) on the level of deprivation (LDI), i.e. on the intensity of Malthusian positive checks.*

5. The regenerating impacts of Malthusian positive checks

Intuitively, one might expect that high mortality should be reducing the size of population and thus that it should be suppressing growth. This is what Malthus expected. "These facts seem to shew that population increases exactly in the proportion that the two great checks to it, misery and vice, are removed, and that there is not a truer criterion of the happiness and innocence of a people than the rapidity of their increase" (Malthus, 1798, p. 34).

Thus, according to Malthus, the smaller is the intensity of misery and vice, the faster should be the growth of the population. Furthermore, his comment suggests that it should be a linear correlation.

If his interpretation of growth is correct, we should expect that the growth rate of population should be *decreasing* with the increasing intensity of Malthusian positive checks, i.e. with the increasing level of deprivation. Furthermore, the high growth rate could be used as an indicator of "the happiness and innocence" because "there is not a truer criterion of the happiness and innocence of a people than the rapidity of their increase."

We are now going to show that Malthusian positive checks stimulate growth, which is hardly surprising because it is well known that poor countries are characterised by a rapid growth of population. Malthus observed this phenomenon of stress-induced growth but he did not follow his observation by a closer investigation perhaps because his access to relevant data was strongly limited. It is also obvious that rapid growth of population in poor countries does not contribute to their happiness.

5.1. Total fertility rate increases exponentially with the intensity of Malthusian positive checks

Total fertility rate is defined as the "number of children that would be born to each woman if she were to live to the end of her child-bearing years and bear children at each age in accordance with prevailing age-specific fertility rates" (UNDP, 2011, p. 142). The dependence of total fertility rate on the level of deprivation, i.e. on the intensity of Malthusian positive checks is shown in Figure 5.

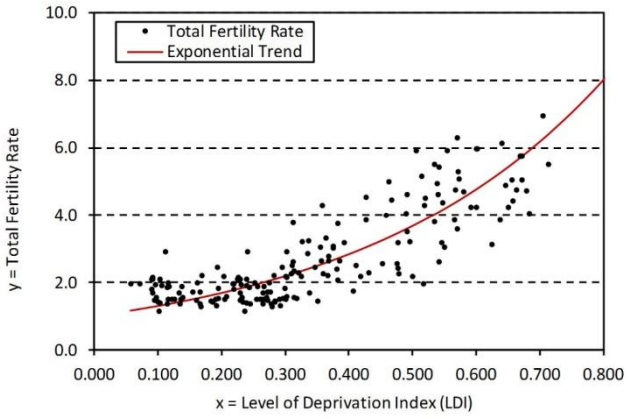

Figure 5. *Total fertility rate increases exponentially with the intensity of Malthusian positive checks, i.e. with the increasing level of deprivation (LDI).*

Analysis of the UNDP data (UNDP, 2011) leads to remarkable results. It shows that while morality increases exponentially with the intensity of Malthusian positive checks, total fertility rate also increases exponentially. This is the first and important indication that the growth of human population is not slowed down by the increased mortality.

5.2. Growth rate is directly proportional to the intensity of Malthusian positive checks

The correlation between the level of deprivation and the growth rate is shown in Figure 6. The data show that, on average, the annual growth rate is directly proportional to the level of deprivation, i.e. to the intensity of Malthusian positive checks. The larger is the intensity of Malthusian positive checks the larger is the growth rate.

Contrary to the intuitive expectations and contrary to the repeated claims of the existence of the mythical epoch of Malthusian stagnation, the growth of human population is not decreased by the Malthusian positive checks but increased. However, when the intensity of Malthusian positive checks is exceptionally high and when they continue over a long time, the growth of population might be temporarily slowed down. This effect was observed in the growth of the world population but even then the temporary disturbance in the growth of population was followed by their more accelerated growth (Nielsen, 2016d).

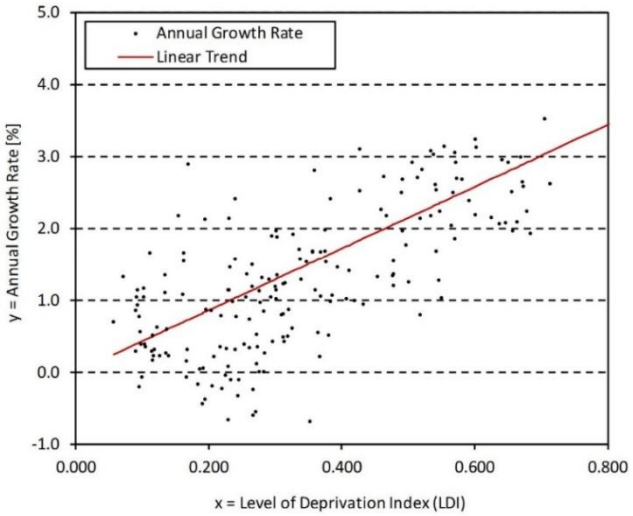

Figure 6. *The dependence of the annual growth rate on the level of deprivation, i.e. on the intensity of Malthusian positive checks.*

The straight line fitting the empirical growth rate data shown in Figure 6 is given by

$$y = m(x - n)\,, \tag{6}$$

where for this particular set of data (UNDP, 2011) m = 4.3 and n = 0.

In countries characterised by the low level of human development, and consequently experiencing high intensity of deprivation and of the associated mortality, the growth of population as given by the UNDP data (UNDP, 2011) was on average about 5 times faster than in countries characterised by the very high human development and experiencing the low level of deprivation and mortality.

5.3. Rate of natural increase is directly proportional to the intensity of Malthusian positive checks

The rate of natural increase is defined as the difference between the death and birth rates and thus excludes the immigration and emigration rates. The correlation between the rates of natural increase and the levels of deprivation can be studied by using the 2002 data for the rates of natural increase (US Census Bureau, 2002) and the 2002 data for the HDI extrapolated from the tabulated data for 2000 and 2005 (UNDP, 2011). Results are presented in Figure 7.

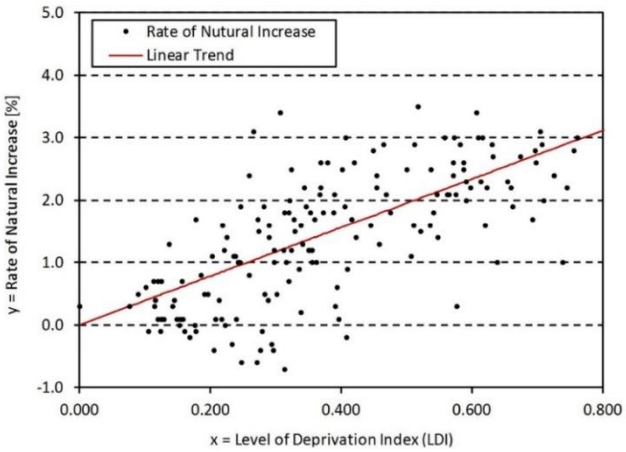

Figure 7. *The dependence of the rate of natural increase on the level of deprivation, i.e. on the intensity of Malthusian positive checks.*

The fitted straight line, represented by the eqn (6), corresponds to $m = 3.9$ and $n = 0$. These data show that the rate of natural increase is also directly proportional to the level of deprivation.

In principle, the rate of natural increase gives a better representation of the impacts of Malthusian positive checks because it is not obscured by contributions from immigrations and emigrations. However, by comparing Figures 6 and 7, we can see that the linear dependence applies to the growth rate and to the rate of natural increase suggesting that contributions from immigration and emigration are in general negligibly small. Individual points might be shifted but the general trend is the same. The gradients of the straight lines fitting the data are also similar, 4.3 for the growth rate and 3.9 for the rate of natural increase. It does not matter whether we are using growth rate or the rate of natural increase, results are the same: contrary to the widely accepted but erroneous doctrine of Malthusian stagnation, the intensified presence of Malthusian positive checks is correlated with the intensified growth of population.

Results presented in Figures 6 and 7 are most surprising. The regenerating impacts of Malthusian positive checks do not just keep the growth rate constant – they stimulate growth and make it even faster.

5.4. Devastating impacts of Malthusian positive checks are correlated with their regenerating impacts

The dichotomy of Malthusian positive checks can be also illustrated by the correlations between the iropposite impacts, the correlations between destructive and regenerating effects. We could study how various forms of mortality (adult mortality, under-five mortality, maternal mortality or deaths by polluted water) are correlated with various forms of regenerating effects (total fertility rate, growth rate and the rate of natural increase). For the listed here effects we would have 12 such correlations. However, this study of multiple correlations can be reduced to a study of two types of correlations: (1) correlations between exponential distributions describing total fertility rate and various forms of mortality, and (2) correlations between exponential and linear distributions, with exponential distributions representing various forms of mortality while linear distributions representing growth rate or the rate of natural increase. As an example, we show two such correlations: (1) the correlation between adult mortality (exponential) and total fertility rate (exponential), displayed in Figure 8 and (2) the correlation between adult mortality (exponential) and the growth rate (linear), displayed in Figure 9.

5.4.1. Correlations between exponential impacts

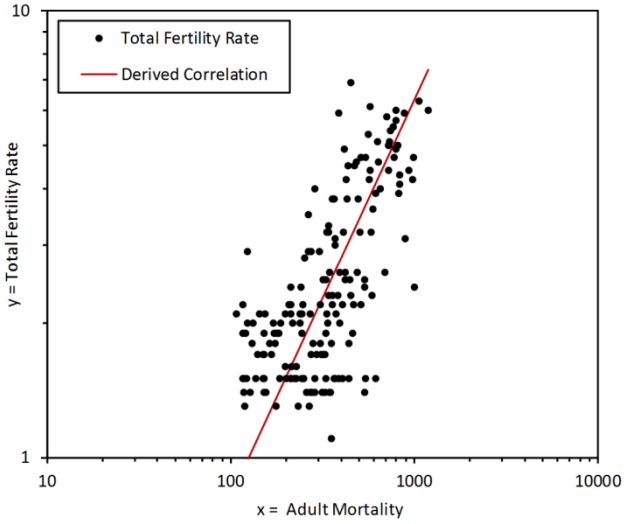

Figure 8. *The dichotomy of Malthusian positive checks: the increasing destructive impacts (mortality) are correlated with the increasing total fertility rate. Similar correlations exist also for under-five mortality, maternal mortality and deaths by polluted water. Parameters are given by the correlations of the LDI with adult mortality and with total fertility rate.*

As we have already seen, adult mortality and total fertility increase exponentially. If we represent mortality by *y*:

$$y = be^{rx} \tag{7}$$

and fertility by *z*:

$$z = b'e^{r'x}, \tag{8}$$

then the correlation between *y* and *z* is given by

$$z = Ae^{B\ln y}, \tag{9}$$

where

$$B = \frac{r'}{r} \tag{10}$$

and

$$A = b'e^{-B\ln b} \quad . \tag{11}$$

The eqn (9) can be also expressed as

$$\ln z = \ln A + B\ln y \tag{12}$$

5.4.2. Correlations between linear and exponential impacts

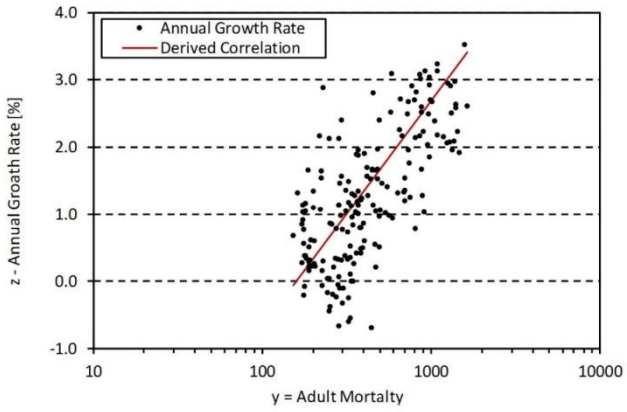

Figure 9. *The dichotomy of Malthusian positive checks: the increasing destructive impacts (mortality) are correlated with the increasing growth rate. Similar correlations exist also for under-five mortality, maternal mortality and deaths by polluted water as well as between the rate of natural increase and all these forms of mortality. Parameters are given by the correlations of the LDI with adult mortality and with the annual growth rate.*

Correlations between the growth rate or the rate of natural increase and various forms of mortality also illustrate the dichotomy of Malthusian positive checks. As we have seen, the rate of natural increase and the growth rate increase linearly with the intensity of Malthusian positive checks while mortality increases exponentially. If we follow similar procedure as outlined earlier for the correlations between mortality and fertility, we shall find that

$$z = m\left[\frac{\ln y}{r} - \left(n + \frac{\ln b}{r}\right)\right] \tag{13}$$

where z is the annual growth rate or the rate of natural increase and y is the mortality, which could be adult mortality, under-five mortality, maternal mortality or deaths by polluted water. For the UNDP data (UNDP, 2011), $n = 0$ and this formula is reduced to

$$z = \frac{m}{r}\left[\ln y - \ln b\right] \tag{14}$$

An example of these correlations is shown in Figure 9. As the intensity of the destructive effects (mortality) of Malthusian positive checks increases, the intensity of the regenerating effects also increases and is reflected in the increased growth rate or in the increased rate of natural increase.

It is generally believed that Malthusian positive checks cause stagnation in the growth of population and in the associated economic growth (see for instance Artzrouni & Komlos, 1985; Desment & Parente, 2012; Galor, 2005a, 2011; Galor & Weil, 1999; 2000; Guest & Almgren, 2001; Hansen & Prescott, 2002; Komlos, 1989; 2000; Komlos & Baten, 2003; Lagerlöf, 2003a; 2001b; Lee, 1997; Leibenstein, 1957; McKeown, 1983; 2009; Nelson, 1956; Olshansky & Ault, 1986; Omran, 1971; 1983; 1998; 2005; Robine, 2001; van de Kaa, 2010; Vollrath, 2011; Wang, 2005; Warf, 2010; Weisdorf, 2004). The concept of Malthusian stagnation is at the root of the established knowledge in demography and in economic

research, the knowledge, which is largely based on conjectures, impressions and even on distorted presentations of data (Ashraf, 2009; Galor, 2005a; 2005b; 2007; 2008a; 2008b; 2008c; 2010; 2011; 2012a; 2012b; 2012c; Galor & Moav, 2002; Snowdon & Galor, 2008).

As discussed elsewhere (Nielsen, 2016j), the currently established knowledgein demography and in economic research, based on the concept of Malthusian stagnation, is scientifically unacceptable. There is now an overwhelming evidence that the so-called Malthusian stagnation never existed in the growth of population and in the economic growth (Biraben, 1980; Clark,1968; Cook,1960; Durand, 1974; Gallant, 1990; Haub, 1995; Kapitza, 2006; Kremer, 1993; Lehmeyer, 2004; Livi-Bacci, 1997; Maddison, 2001; 2010; Mauritius, 2015; McEvedy & Jones, 1978; Nielsen, 2013a; 2013b; 2013c; 2014; 2015; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; Podlazov, 2002; Shklovskii, 1962; 2002; Statistics Mauritius, 2014; Statistics Sweden, 1999; Taeuber & Taeuber, 1949; Thomlinson, 1975; Trager, 1994; United Nations, 1973; 1999; 2013; von Hoerner, 1975; von Foerster, Mora & Amiot, 1960; Wrigley & Schofield, 1981). The investigation of the UNDP data (2011) contributes to the explanation why there was no stagnation. One of the contributing factors was the dichotomy of Malthusian positive checks. As originally noticed by Malthus and as now confirmed by the study of the UNDP data (UNDP, 2011) the destructive action of Malthusian positive checks is accompanied by their regenerating impacts. Destruction induces regeneration.

5.5. Summary of the observed correlations

Summary of the observed correlations between the Level of Deprivation Index (LDI) representing the intensity of Malthusian positive checks and a series of indicators illustrating the standard of living, the destructive impact of Malthusian positive checks and their regenerating impacts is presented in Table A1 (in the Appendix). This table includes also correlations between the destructive and regenerating impacts of Malthusian positive checks.

5.6. Hunger and famines are correlated with the intensified growth of population

The dichotomy of Malthusian positive checks can be also studied by investigating impacts of hunger. As with other, specifically mentioned indicators describing levels of deprivation, hunger is just the reflection of the whole spectrum of Malthusian positive checks. “Natural disasters, climatic shocks, conflict, and insecurity are major causes of hunger. But hunger’s root causes are tied to a lack of access by individuals to the resources they need to produce, sell, and buy food” (Sheeran, 2008, p. 180). “The tragic fact is that, although our planet produces enough food for everyone, one person in seven still goes to bed hungry each night. 25,000 people die every day – including one child every 5 seconds – from hunger-related causes” (Sheeran, 2008, p. 180). “The overall finding is that 3.1 million children younger than 5 years die every year from undernutrition; that is a staggering 45% of total child deaths in 2011” (Horton & Lo, 2013, p. 371).

Hunger appears to be one of the leading causes of death in the world. “Every year over 10 million people die of hunger and hunger-related diseases. Nearly six million of these are children under the age of five; that is one child’s death approximately every six seconds.” (Gibson, 2012, p. 18). This should be compared with other leading causes of death in the world in 2012: ischaemic heart disease, 7.4 million deaths per year; stroke, 6.7 million; COPD, 3.1 million; lower inspiratory infections, 3.1 million; trachea bronchus lung cancers, 1.6 million; HIV/AIDS, 1.5 million; diarrhoeal diseases, 1.5 million; diabetes mellitus, 1.5

million; road injury, 1.3 million; hypertensive heart disease, 1.1 million (WHO, 2014).

Again, it is repeatedly but erroneously claimed that lethal effects of hunger and famines suppress the growth of human population and create a stagnant state of growth. We shall demonstrate that such is not the case. These popular and widely-accepted interpretations are incorrect. They are based on scientifically unsupported dogmas (Nielsen, 2016j).

5.6.1. Evidence from Africa

Table A2 (in the Appendix) and Figure 10 present a series of growth-related indicators for two groups of African countries, one group where hunger stress is $\geq 35\%$ and another where hunger stress is less than 5%.

Data presented in Table A2 and Figure 10 are based on the examination of three sources of reference (PRB, 2010; UNDP, 2011; WFP, 2010). In Figure 10, birth and death rates are expressed in percent while infant mortality rate in per cent of live births.

Table A2 and Figure 10 show that on average, and for these set of data, countries exposed to high level of hunger stress experience 71% higher intensity of Malthusian positive checks as expressed by the LDI and have strongly reduced access to natural resources, as reflected in their ecological footprint, when compared with countries experiencing low hunger stress. Countries with high hunger stress experience 39% higher death rate and a massive 120% higher infant mortality rate. However, for these countries, total fertility rate is 47% higher, birth rate is 35% higher, the rate of natural increase is also 35% higher and the population increase factor is 26% higher, all these indicators showing that the natural response to the lethal Malthusian checks is the increased rate of procreation and the intensified process of regeneration. Thus, contrary to the generally accepted interpretations, hunger does not reduce the growth of human population but is associated with a faster growth.

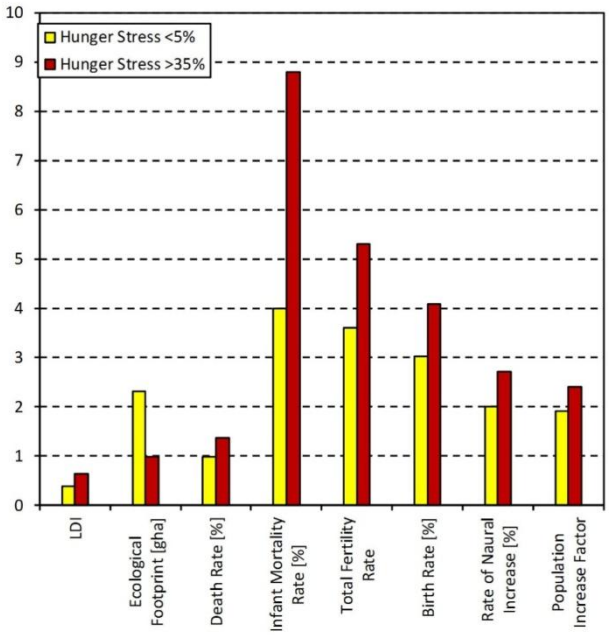

Figure 10. *The dichotomy of Malthusian positive checks as reflected in the intensity of hunger stress. Populations suffering high hunger stress experience a higher death rate and a higher rate of infant mortalitythan populations experiencing a small hunger stress. However, populations suffering high hunger stress are also characterised by a higher total fertility rate, higher birth rate, higher rate of natural increase and higher population increase factors.*

It is, of course, impossible to isolate hunger as a single stress factor. Malthusian positive checks are interconnected. However, if for instance, hunger stress increases the susceptibility to infectious diseases, then the primary stress factor is still hunger.

Data make it clear that in countries suffering high hunger stress population growth is *faster* than in countries experiencing significantly lower hunger stress. Clearly, Malthusian positive checks bring not only the destruction as reflected in the increased death tolls but also the regeneration. Furthermore, the regeneration process is more powerful than the process of destruction because the growth of population is not just at the same level as in countries experiencing low hunger stress but faster.

5.6.2. Evidence from China

A prominent example of devastating impacts of Malthusian positive checks associated with famines is China. "Between the years 108 B.C. and 1911 AD, there were 1828 famines or one nearly every year in some of the provinces. Untold millions have died of starvation. In fact, the normal death rate may be said to contain a constant famine factor" (Mallory, 1926, p. 1). However, China is also an excellent example of regenerating impacts of Malthusian positive checks."In spite of the tremendously high death rate, particularly of infants, due to lack of modern medical knowledge, in spite of the depopulating effect of terrible famines, and in spite of the immense loss of life caused by civil wars we find today a denser population on the plains than ever before; and since there has been no appreciable influx from other countries we much ascribe the present conditions to the excessive birth rate" (Mallory, 1926, p. 87).

6. The dichotomy observed by Malthus and in nature

While Malthus is well known for suggesting lethal effects of positive checks, he is not so well known for being aware of the existence of a competing mechanism, the mechanism of spontaneous regeneration and preservation of identity.

"The absolute population at any one period, in proportion to the extent of territory, could never be great, on account of the unproductive nature of some of the regions occupied; but there appears to have been a most rapid succession of human beings, and *as fast as some were mowed down by the scythe of war or of famine, others rose in increased numbers to supply their place*. Among these bold and improvident Barbarians, population was probably but little checked, as in modern states, from a fear of future difficulties (Malthus, 1798, p. 15. Italics added).

If Malthus had access to the data available to us he would have probably presented a more appropriate description of people exposed to lethal effects of positive checks. We would be reluctant to describe people living in poor countries as "bold and improvident Barbarians." We also would not like to use the same description to parents of the post-war baby boomers.

Apart from this general observation, Malthus presents also data, which suggest that high-intensity positive checks are linked with the intensified process of regeneration (Malthus, 1798, pp. 36-40). He has noticed, for instance "that the greatest proportion of births to burials, was in the five years after the great pestilence" (Malthus, 1798, p. 37). He concludes that "Great and astonishing as this difference is, we ought not to be so wonder-struck at it as to attribute it to the miraculous interposition of heaven. The causes of it are not remote, latent and mysterious; but near us, round about us, and open to the investigation of every inquiring mind" (Malthus, 1798, p. 40). He was convinced that these incidents of intensified growth, after the episodes of epidemics, were not only the manifestation

of the natural law of growth but also that they should be closely examined. It is, therefore, disappointing that numerous scholars who refer to the work of Malthus overlooked his suggestion that the effects of regeneration should be further examined. Malthus also lists many examples of successful regeneration in such places as Flanders, Palestine, London, Turkey, Egypt, China, Naples and Lisbon (Malthus, 1798, p. 35).

While emphasising the importance of food in supporting the growth of human population, he did not fail to notice that people can "live almost upon the smallest possible quantity of food" (Malthus, 1798, p. 41), which implies that hunger or famines should not be immediately identified as factors controlling the growth of population. It is incorrect to suggest that "Malthusian positive checks (mortality crises) maintained a long-run equilibrium between population size and the food supply" (Komlos, 1989, p. 194). It is incorrect to claim that "the food-controlled homeostatic equilibrium had prevailed since time immemorial" (Komlos, 2000, p. 320). It is not immediately obvious the "Throughout human history, epidemics, wars and famines have shaped the growth path of population" (Lagerlöf, 2003b, p. 435).

Malthus uses China as an example where "the lower classes of people are in the habit of living almost upon the smallest possible quantity of food and are glad to get any putrid offals that European labourers would rather starve than eat" (Malthus, 1798, p. 41). He also cautions against using food as a factor controlling the growth of population. He points out twice in his book that in some cases population may "permanently increase without a proportional increase in the means of subsistence" (Malthus, 1798, pp. 41, 43). Furthermore, he points out that there could be "some variations in the proportion between the number of inhabitants and the quantity of food consumed, arising from the different habits of living that prevail in each state" (Malthus, 1798, p. 42). Food consumption is not proportional to the size of population. The relation between food consumption and the growth of population is not immediately obvious.

Malthus placed a significant emphasis on the role of positive checks but he also made an attempt to present a balanced interpretation of growth, a balanced view which is conspicuously missing in the numerous publications referring to Malthus and describing erroneously the effects of Malthusian positive checks as Malthusian stagnation. While making attempts to praise Malthus for his work such publications are in fact diminishing the importance of his contribution.

His early observations, combined with the vast body of data available now to us, help to understand the mechanism of growth of human population. It is a process, which can be influenced by the devastating impacts of Malthusian positive checks but also a process, which is influenced by their regenerating impacts.

The phenomenon of regeneration noticed and recorded by Malthus is similar to the well-known process observed in nature. It is the natural and spontaneous process of self-preservation of living organisms triggered by stressful conditions. It is the resilience of ecological systems (Holling, 1973). There are numerous examples and definitions of this omnipresent phenomenon.

According to Cumming et al. (2005, p. 976), resilience is "the ability of the system to maintain its identity in the face of internal change and external shocks and disturbances." The definition proposed by the National Research Council (NRC) is "the continued ability of a person, group, or system to adapt to stress – such, as any sort of disturbance – so that it may continue to function, or quickly recover its ability to function, during and after stress" (NRC, 2011, pp. 13, 14). "Resilience is the ability to handle stresses or recover from disturbances or shocks" (Bapna, McGray, Mock & Withey, 2009, p. 3). "In general, resilience refers to a system's capacity to deal with change and to continue to develop" (Boyd, et al.,

2008, p. 391). There are also many other definitions of resilience, all describing either the ability of a quick and efficient recovery or the ability to cope with stress.

Malthus noticed the existence of this mechanism of regeneration. This process is also well known in science but for reasons, which are hard to understand, it is overlooked in publications based on the erroneous assumption of the existence of the epoch of Malthusian stagnation. While repeatedly describing the lethal effects of Malthusian positive checks, a balanced interpretation suggested originally by Malthus is missing.

7. Summary and conclusions

Using the UNDP data (UNDP, 2011), we have investigated impacts of Malthusian positive checks. We have assumed that a convenient way of measuring the intensity of Malthusian positive checks is to use the Level of Deprivation Index (LDI), which we defined using the well-known Human Development Index (HDI). This approach allows not only for studying impacts of Malthusian positive checks but also for describing them mathematically. Our empirical formulae are simple but mathematical formulae do not have to be complicated to be useful.

First, we have investigated how the intensity of Malthusian positive checks is reflected in the standard of living as represented by the ecological footprint (EF), income per capita, (GDP/cap), levels of severe poverty, access to clean water and access to sanitation facilities. We have found that the ecological footprint (EF) decreases hyperbolically with the intensity of Malthusian positive checks while the GDP/cap decreases exponentially. We have also found that severe poverty, inadequate access to clean water and to sanitation facilities depend linearly on the intensity of Malthusian positive checks. However, we have also found that these linear correlations are characterised by certain thresholds.

Thus, our analysis indicates that severe poverty can be eliminated without the necessity of reducing the intensity of Malthusian positive checks or equivalently the levels of deprivation to zero or close to zero. The level of the severe poverty reaches its zero value at a certain threshold of the intensity of Malthusian positive checks. A significant reduction in the level of severe poverty can be achieved by only a relatively small increase in the average income per capita in poor countries.

We have investigated the lethal effects of Malthusian positive checks and we have found that *mortality* increases *exponentially* with the increasing level of deprivation, i.e. with the increasing intensity of Malthusian positive checks. However, we have found that *total fertility rate* also increases *exponentially* with the increasing intensity of Malthusian positive checks.

One of the important results of our analysis is that the growth rate *increases* with the intensity of Malthusian positive checks. The rate of natural increase also increases. The larger is the intensity of the destructive impacts of Malthusian positive checks, the faster is the growth of population. The destructive impacts of Malthusian positive checks are not just balanced by their regenerating process – they stimulate an even faster growth. These results suggest that the essential step in controlling the growth of population is to reduce the levels of severe poverty. Helping poor countries to help themselves is not an option.

We have also investigated correlations between destructive and regenerating impacts of Malthusian positive checks and again we have derived simple mathematical formulae describing these correlations. We have demonstrated that the intensity of the regenerating process increases with the increasing intensity of the destructive process of Malthusian positive checks. We have derived a general formula showing how the total fertility rate increases with the increasing mortality. We have also derived a simple mathematical formula showing how the rate of

natural increase and the growth rate increase with the increasing mortality. We have presented diagrams for the adult mortality but the same formulae apply also to other forms of mortality such as maternal mortality, under-five mortality and the mortality caused by polluted water.

Our investigation shows that contrary to the interpretations based largely on intuition and impressions, growth of population is not controlled by the increased mortality. On the contrary, the increased mortality stimulates growth. Our study suggests that in order to have better control of the growth of human population, levels of deprivation experienced by poor countries should be significantly reduced. The first and the essential step is to improve the economic status of these countries. However, helping poor countries to increase their income per capita is only a partial solution. This step should be accompanied by making a wider range of *accessible* options such as options for education and employment available to people living in poor countries. The improvement of economic status should also go hand in hand with the improvement in gender equality, which will facilitate better family planning. Only by improving the living conditions of poor countries we can hope to have a better, long-term, control of the growth of human population and of its stabilization. Successful control of the growth of human population is essential for controlling our ever-increasing ecological footprint (Ewing, et al., 2010; WWF, 2010) and for finding at least some solutions to the current critical trends shaping the future of our planet (Nielsen, 2006).

Appendix

Table A1. *Mathematical dependence of listed indicators (y) on x = LDI (the intensity of Malthusian positive checks) with the corresponding parameters describing the UNDP data (UNDP, 2011). The table includes also two types of correlations between destructive and regenerating impacts.*

Indicator	Formula	Parameters
Standard of living		
Ecological footprint (EF)	$y = ax^{-1}$	a = 0.646
GDP/cap	$y = be^{rx}$	b = \$71,144, r = -6.97
Population in severe poverty	$y = m(x-n)$	m = 190, n = 0.358
Population below the poverty line	$y = m(x-n)$	m = 195, n = 0.308
Multidimensional Poverty Index	$y = m(x-n)$	m = 1.23, n = 0.293
Pop. with no access to clean water	$y = m(x-n)$	m = 175, n = 0.371
Pop. with no access to san. facilities	$y = m(x-n)$	m = 220, n = 0.327
Lethal impacts of positive checks		
Deaths due to polluted water	$y = be^{rx}$	b = 5, r = 9
Maternal mortality	$y = be^{rx}$	b = 3.58, r = 8.59
Under-five mortality	$y = be^{rx}$	b = 2.4, r = 6.7
Adult mortality	$y = be^{rx}$	b = 62.42, r = 2.93
Regeneratingimpacts		
Total fertility rate	$y = be^{rx}$	b = 1, r = 2.6
Growth rate	$y = m(x-n)$	m = 4.3, n = 0
Rate of natural increase (RNI)	$y = m(x-n)$	$m = 3.9,\ n = 0$
Regenerating *v*lethal impacts		
Total fertility rate (z) *v* mortality (y)	$\ln z = \ln A + B \ln y$	eqns (7) – (12)
Growth rate or RNI (z) *v* mortality (y)	$z = \frac{m}{r}\left[\ln y - \ln b\right]$	eqn (13)

Table A2.*The dichotomy of Malthusian positive checks reflected in the contrasting levels of hunger stress*

		Destruction		Regeneration			
Country	**LDI**	**DR**	**IM**	**TFR**	**BR**	**RNI**	**PIF**
Hunger Stress: ≥ 35%							
Angola	0.514	15	102	2.7	43	2.8	2.4
Burundi	0.684	10	66	6.4	42	3.2	2.7
Chad	0.672	16	125	6.0	45	2.9	2.4
CARent. Afr.	0.657	15	102	4.7	37	2.1	2.1
DRCongo	0.714	17	111	6.1	45	2.8	2.2
Eritrea	0.651	8	43	4.7	34	2.6	1.9
Ethiopia	0.637	10	77	5.3	37	2.7	2.0
Malawi	0.600	15	84	5.7	42	2.7	2.4
Mozambique	0.678	14	86	5.6	41	2.8	2.6
Sierra Leone	0.674	15	89	5.0	37	2.2	2.5
Zambia	0.570	15	84	6.3	46	3.1	3.3
Average Values	**0.641**	**13.6**	**88.1**	**5.3**	**40.8**	**2.7**	**2.4**
Hunger Stress: < 5%							
Algeria	0.602	5	22	2.3	19	1.5	1.3
Egypt	0.356	5	23	2.9	25	2.0	1.5
Gabon	0.326	9	45	3.4	27	1.8	1.8
Libya	0.240	4	14	2.5	22	1.8	1.4
Morocco	0.418	6	30	2.2	19	1.3	1.2
South Africa	0.381	14	48	2.4	21	0.6	1.1
Tunisia	0.302	6	18	2.1	18	1.2	1.2
Average Values	**0.375**	**9.8**	**40.0**	**3.6**	**30.2**	**2.0**	**1.9**
Ratio	**1.71**	**1.39**	**2.20**	**1.47**	**1.35**	**1.35**	**1.26**

LDI – Level of Deprivation Index; DR – Death Rate; IMR – Infant Mortality Rate; TFR – Total Fertility Rate; BR – Birth Rate; RNI – Rate of Natural Increase; PIF – Population Increase Factor; CAR – Central African Republic; DRC – Demographic Republic of Congo; Ratio – High stress/Low stress.

Death and birth rates are per 1000 of the population. Infant Mortality Rate is defined as "The annual number of deaths of infants under age 1 per 1,000 live births" (PRB, 2010). The Rate of Natural Increase is in percent. Population Increase Factor gives the projected population in 2050 as a multiple of the population in 2011.

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