The Future Collapse of the Global Human Population.

By

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Abstract.

As a follow-up to a preceding paper (Blaber, 2024 [1]), this paper will supply a simple mathematical model of the collapse of the global human population coinciding with that of the advanced industrial capitalist society predicted therein, and expand on the thesis presented earlier, taking account of such issues as global supply chains and the vulnerability of nodes in complex systems, giving rise to social entropy. The super-exponential growth of human population was enabled by the extraction and burning of fossil fuels, and renewable forms of energy will not be able to sustain a remotely similar level of population.

Keywords: mathematical model; global human population collapse; collapse of advanced industrial society; global supply chains; nodes in complex systems; social entropy; super-exponential growth in population; extraction and burning of fossil fuels; renewable energy.

Statement re conflicts of interest: the author declares he has no conflict(s) of interest, and has received no funding for his research from any source, public, private or voluntary sector.

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[1] Introduction.

If the reasoning of Rees' arguments in Rees (2020 [2]) and (2023a [3]) and that contained in Blaber [1] is correct, a major – and quite precipitous – reduction in the size of the global human population at some point in the next two to three decades is to be expected. This assertion is reinforced by the claims contained in Daily and Ehrlich

(1992 [4]), Daily, Ehrlich, A.H. and Ehrlich, P.R. (1994 [5]) and Blaber (2022 [6]).

If humanity's population dynamics could be described by the logistic equation for population growth first adumbrated by Verhulst (1845 [7]) and brought to widespread academic attention by Reed and Pearl (1927 [8]), given as written by Salisbury (2011 [9], p.9); see Strang and Herman (no date, [10]) for its solution, then:

$$dP/dt = rP(1 - P/K) \,. \tag{1}$$

Here, P represents population, t, time, r = the annual rate of population growth, and K the carrying capacity, defined as the maximum number of (people, in this case – but any organism, generally) that the environment can sustain indefinitely.

Data from the US Census Bureau (2024 [11]), informs us the mid-year world human population for 2024 was 8.057 billion, and that for mid-year 2050 was expected to be 9.755 billion, implying a mean annual growth rate, r, of 0.81%, until that point.

If we then, on the basis of the argument in Blaber [6, p.11], insert a carrying capacity, K, of 1 billion, which (see op.cit., and Kumar, 2024 [12]) was the global human population in 1825, it is easily seen that the 2050 population (without carrying capacity, K), of

$$P = P_0(rt + 1) = 9.755 \text{ billion} \tag{2}$$

is completely unsustainable, because the *present* population is also unsustainable: $(1 - P_0/K) = -7.057$.

The question then becomes: how, then, is the unsustainable being (temporarily) sustained? The answer is supplied for us by Rees (2023b [13]), who notes, on p.3:

> **'*Homo sapiens* had been around for perhaps 250,000 years before our population topped one billion early in the 19th century, but it took only 200 years... for it to balloon to nearly eight billion by early in the 21st century. While improvements in medicine, public sanitation and population health contributed, it was mainly the consumption of coal, oil and**

> **gas that made this spectacular expansion possible (half the [fossil fuels] ever used have been burned since 1990). Fossil fuels are the energetic means by which humans extract, transport and transform the prodigious quantities of food and other material resources needed to support our burgeoning billions all over the world.'**

It is fossil fuel consumption, mainly by means of combustion – and *only* fossil fuel consumption, over the past two hundred years or so – that permits Sojecka and Drozd-Rzoska (2024 [14]) to argue for a 'super-Malthusian' mathematical growth model for the global human population.

The damage caused to the environment, the climate and public health by fossil fuel-related carbon and aerosol emissions is widely acknowledged, but, as Moriarty and Honnery (2020 [15]) point out, a '100% global renewable energy system' in 2050 is probably infeasible, given continuing annual economic growth between now and then, which implies both increased energy consumption and increased population.

For 'probably', read 'certainly', for – as noted in [1, p.13] – fossil fuel combustion will *still* contribute 438 EJ (Exajoules; 1 EJ = 1×10^{18} J) of the 760 EJ of primary energy consumption in 2050, i.e., 57.63%. Global primary energy consumption was 619.63 EJ in 2023, according to Statista (2024, [16]); of which coal, oil and gas contributed ~85.31%, or 528.61 EJ, according to Our World in Data (2024a, [17]); this implies a reduction in global primary energy consumption from fossil fuels of 90.61 EJ between 2023 and 2050, or 17.14%, a modest average 0.63% p.a., and much less than needed. For the causal link between a global capitalist economy's need for economic growth and its need for an ever-increasing population, see Blaber (2023a [18], p.3). The US Energy Information Administration (EIA, 2023 [19]) asserts:

> **'Our projections highlight a key global insight – global energy-related CO_2 emissions will increase through 2050 in all IEO2023 [*International Energy Outlook* 2023] cases except our Low Economic Growth case. Our projections indicate that resources, demand, and technology costs will drive the shift from fossil to non-fossil energy sources, but current policies are not enough to decrease global energy-sector**

> **emissions... economic and population growth drive the increase in emissions.'**

[2] The Model Developed.

Lima (2024 [20]), referring to the 'Great Acceleration' in the growth of human population, accepts, as does Rees [13], that the consumption of fossil fuels since the Industrial Revolution enabled this expansion in numbers. As he says (pp.1-2):

> **'Modern civilization has been made possible by the massive and increasing combustion of fossil fuels; the global use of hydrocarbons for human fuel has increased nearly 800-fold since 1750 and approximately 12-fold in the 20th century... The accelerated expansion of the global human population and economies during the past 70 years has only been possible because of the expansion in the use of fossil fuels.'**

However, as he also notes (ibid.):

> **'we will face two significant problems with the use of fossil fuels. First, oil reserves have been declining since 1970... second, there are negative environmental consequences of burning [carbon], such as global warming.'**

Oil and gas reserves are expected to be completely depleted in 52 and 45 years, or by 2076 and 2069, respectively (Our World in Data, 2024b [21]).

Lima (op.cit., pp.3ff.) constructs a mathematical model of human population dynamics related to fossil fuel consumption, economic growth and energy return on energy invested (EROI) for the period 1800-2020, whose details need not detain us, but he concludes (p.13):

> **'the structural instability of cooperation/competition dynamics fueled by a new energy source is the signature of population transitions in human societies and may be the ultimate cause of the human propensity toward unsustainability and socio-ecological collapse... The energetic stock of fossil fuels supported our recent expansive**

> **population process, and future limitations in energetic supply will make our expansive global society vulnerable to diminishing returns.'**

If we turn to mathematical models of population *collapse*, as opposed to growth, there are a number of examples, but two such are Dornberger *et al.* (2012 [22]) and Bologna and Flores (2008 [23]), neither of which, unfortunately, can serve our purposes here.

In their model of human population dynamics, which they term 'HANDY' (Human And Nature Dynamics), Motesharrei, Rivas and Kalnay (2014 [24]), claim that unequal societies, such as our own, will collapse irreversibly (see Figure 6b, p.98). However, their timescale for what they term a 'fast' process seems somewhat slow to *this* author, as we are talking about decades, not centuries.

There seems to be no alternative, in fact, but to retain the concept of carrying capacity as first employed by Verhulst [7], and to accept that there will come, at some time in the next two to three decades, an inflection point (see Weisstein, no date [25]), entailing a change of sign in the value of the human population growth rate, r, and a large increase in its absolute value.

If we take the projected 2050 population of 9.755 billion as our new base population, P'_0, $(1 - P'_0/K) = -8.755$. This will have a catastrophic impact on human population, unmitigated by the dubiously beneficial effects of carbon combustion and all the polluting and biodiversity-destroying consequences of our industrial and agricultural activities (UNEP, 2020 [26]; Li *et al*, 2024 [27]). The departure from homeostasis (see Lee, 1987 [28]) will have become unsupportable by this time.

If 2050 is our base year, and t = 1 year, so we are referring to the global population of mid-2051, then if:

$$r = -e^{-Kt/P} = -1/e^{Kt/P} = -0.902567741 \,, \tag{3}$$

implying a rate of decline of 90.2567741% p.a. from mid-year 2050 to mid-year 2051, the global human population would thus fall to 950,451,687, or less than a K of 1 billion. Furthermore, this is without postulating a nuclear war, which would be likely to have an even more devastating impact on human numbers, as well as on biodiversity and the environment. There is no need to suppose that (3) will hold once equilibrium, or homoeostasis, is restored. When $P = K$ (or is $\sim K$):

$$r = 0.(-e^{-Kt/P}) = 0/e^{Kt/P} = 0/e^{t} = 0\ . \tag{4}$$

Such an extreme fall in population as envisaged by (3) with $t = 1$ year may be regarded as unrealistic, but is nevertheless possible in the right circumstances, i.e., those of a catastrophic (but ‘one-off’) collapse, and constitutes an exponential decay equation (for another example, see Schiraldi, 2020 [29], p.3). (4) represents the case of population stability, where annual global birth and death numbers are equal.

In a scenario where $t = 10$ years, (3) gives an $r = -0.3587551$, or a decline of 35.87551% in global population in ten years (a mean of 3.587551% p.a.). Restating:

$$e^{Kt/P} = -1/r = -r^{-1}\ , \tag{5a}$$

which reduces to:

$$e^{t} = 0/r = 0.r^{-1} = 0. \tag{5b}$$

when $P = K$, which entails:

$$0.re^{t} = 0\ . \tag{5c}$$

We find that this is consistent with (3) and (4) above.

[3] Global Supply Chains, the Vulnerability of Complex Systems, and Social Entropy.

Wagner and Bode (2006 [30]) undertook an empirical investigation into the vulnerability of global supply chains, concluding that modern supply chains have become prone to disruptions, their vulnerability to disturbance and disruption has increased, and the more complex and tightly coupled the supply chain, the more prone it becomes to what they term ‘untoward events’.

Wagner and Neshat (2010 [31]) note that

> **‘As a result of changes in the economic, business and ecological environments, modern supply chains seem to be more vulnerable than ever before...’ (p.1).**

Of particular relevance, of course, is the ecological environment, but the present author has pointed to the possibility – and even the strong possibility – of a deterioration in the economic one, see Blaber (2023b, 2024 [32]).

Free and Hecimovic (2021 [33]) argue that the COVID-19 pandemic exposed the vulnerability of global supply chains, which, they say, are underpinned by ‘the rise and impacts of neoliberal globalism’ (p.2, pdf.). They refer to the possibility of increased protectionism (p.14, pdf.), and populist politics in the US has certainly increased the pressure for protectionist trade policies there (see Ehrlich, S.D. and Gahagan, 2023 [34]), with an inevitable increase in protectionism elsewhere – for example, in the response to President Trump’s higher tariffs on imported steel (Handley, Kamal and Monarch, 2020 [35]), and that to the higher US tariffs on imported semiconductors (Donnelly, 2023 [36]). Paché (2022 [37]) notes how Russia’s invasion of Ukraine exposed the fragility of global supply chains, and the problem has been particularly acute for global food supply chains (Jagtap *et al.*, 2022 [38]).

A supply chain is an example of a complex system (Brintup, Yang and Tiwari, 2015 [39]). Efatmaneshnik, Bradley and Ryan (2016 [40]) inform us that ensembles of such complex systems (a ‘system of systems’):

> **‘can be vulnerable to sudden catastrophic collapse as a result of small and insignificant partial functionality losses in one of the constituent systems’ (p.294).**

It is a general rule that the greater the complexity, the greater the vulnerability to sudden and catastrophic collapse (Tainter, 1988 [41]). In an interview with Ehrenreich (2020 [42], p.7, pdf.), Tainter tells us that:

> **‘Only complexity... provides an explanation that applies in every instance of collapse. We go about our lives, addressing problems as they arise. Complexity builds and builds, usually incrementally, without anyone noticing how brittle it has all become. Then some little push arrives, and the society begins to fracture. The result is a “rapid, significant loss of an established level of sociopolitical complexity.” In human terms, that means central governments disintegrating and empires fracturing into “small, petty states,” often in conflict with one another. Trade routes seize up, and cities are abandoned. Literacy falls off, technological knowledge is lost and populations decline sharply. “The world”... “perceptibly shrinks, and over the horizon lies the unknown.”’**

This process is, in turn, an example of ‘social entropy’ (Stepanic *et al.*, 2000 [43]), which can be related to entropy in thermodynamic and information (or ‘Shannon’) terms, see Mavrofides *et al*. (2011 [44]); Rizescu and Avram (2014 [45]); Zingg *et al*. (2019 [46]). For a thermodynamically-related version of a social entropic model of civilisational collapse, see Rees (2008 [47]); Dobruskin (2021 [48]).

[4] Conclusion.

Wen and Deng (2020 [49]) argue that the more parts (or ‘nodes’) there are in a system, and the more relationships there are between them (‘edges’), the more vulnerable that system becomes to breaking down, employing the concept of entropy to make their case. Clearly, the more nodes and edges, or parts and relationships, there are, the more complex the system, and therefore the more fragile it is, and more susceptible to collapse.

We have seen from the above that a collapse in the size of the global human population is not merely a possibility, but a certainty (Brozović, 2023 [50]). The *present* level of population is already unsustainable, consuming the equivalent of 1.75 Earth’s worth of its biocapacity (Global Footprint Network, 2024 [51]), measured in global hectares (Global Footprint Network, 2003-2024 [52]).

If our population (P) and consumption (AT) keep on growing, so will the deleterious impact we have on the ecology of our planet, as

Ehrlich, P.R. and Holdren (1974 [53], p.288) noted, famously. We cannot, and ought not, to assume that the planet will simply take that assault ‘lying down’, and that there will be no consequences for us from it, a point made in the starkest possible terms by Lovelock (2007 [54]).

Equation (3) above, with t = 1 year, will be the result, unless we make much bigger voluntary reductions in our population, consumption and various forms of pollution than currently proposed, starting now.

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