Global Heating and the Demographic Future

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‘Humankind cannot bear very much reality’—T. S. Eliot, *Four Quartets*

Abstract

It was argued at the IUSSP conference in Tours that avoidance and denial have characterized humanity’s response to ‘global warming’, and that this would continue. Illustrative calculations showed that even if per capita CO_2 emissions in each world region remained constant between 2000 and 2050 there would still be a major rise in total CO_2 emissions—from population growth. Moreover, the actual rise would be much greater—due to increases in per capita emission levels. The present paper shows that recent trends confirm these points. Thus, during 2000-19 world consumption of fossil fuels rose by 45 percent, and atmospheric CO_2 rose from 370 to 411 ppm. The much-vaunted Paris Agreement avoids direct mention of the negative-emission technologies that are required to achieve its aims. The paper then explores the future through a demographic lens. It illustrates that seemingly distant dates are actually fairly close. It documents the—largely unnoticed—fact that the growth rates of both atmospheric CO_2 and the world’s surface temperature are *accelerating*. It argues that a doubling of atmospheric CO_2 over preindustrial levels is likely to occur before 2100. Relatedly, the Paris Agreement’s declared aim of restricting the temperature rise to less than 2°C borders on the fanciful. Furthermore, the paper argues that, for climate-related reasons, after 2050 world population growth is likely to be much less than is currently projected. Approaches are mentioned through which the influence of global heating on the world’s demographic future might be better explored.

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Introduction

A paper presented at IUSSP Tours argued that social and political responses to the problem of 'global warming' involved a huge amount of avoidance and denial—and that this would continue. Moreover, due to the heavy dependence of economic growth on fossil fuel use, major rises in the future consumption of coal, oil, and natural gas were inevitable. Illustrative calculations showed that even if the level of per capita CO_2 emissions in each world region remained constant (as in the year 2000) by 2050 global CO_2 emissions from burning these fuels would increase by about 28 percent—i.e., from about 23.2 to around 29.6 gigatons ($GtCO_2$). This increase would come solely from projected population growth. However, the total volume of CO_2 emissions would definitely rise by very much more than this—because in most world regions levels of per capita CO_2 emissions were likely to increase. The result would be a major rise in atmospheric CO_2 and therefore, in all likelihood, the world's temperature. Serious behavioural change to limit carbon emissions was viewed as unlikely. Therefore, the broad sway of future events was seen as set to run its course (see Dyson 2005).[1]

Against this backcloth, the present paper begins by reviewing relevant changes over the first two decades of the current century. It shows that, in all main respects, the situation has got very much worse. Indeed, there is disturbing evidence of an *acceleration* in both the rate of atmospheric CO_2 increase and the rate of global temperature rise. The paper then considers the implications of these worrying developments for future demographic change. It argues that likely consequent rises in socio-political volatility may well have major consequences for population trends—especially from around mid-century. Of course, there is uncertainty about what will happen, particularly at lower levels of aggregation. Nevertheless, there is a need to be more imaginative—and honest—when considering the effects of future global heating on future demographic trends.

Recent Trends

So, two decades into the new century, how have things progressed? At first sight, the situation may seem to have improved. For example, there is probably now greater public awareness of: the case for reducing/limiting/lowering CO_2 and other greenhouse gas (GHG) emissions; the benefits of solar/wind/geothermal/renewable/energy; the advantages of ethanol/biodiesel/hydrogen/fuels; ideas such as carbon budgets and carbon trading; and, progress in relation to integrated energy systems and batteries. This list could easily be extended. And the cost of many of the new technologies has plummeted. Increasingly, landscapes contain solar and wind power stations, and there are electric and hydrogen-fuelled vehicles on the road. There is also a vast amount of associated hype—e.g., with regard to 'sustainable' development. And the threat of global heating, and lack of urgent political action, have been highlighted by activists such as Greta Thunberg and movements like Extinction Rebellion. Also, there appears to have been some progress on the international stage. Above all, the Paris Agreement of 2015 aims to restrict the global temperature rise to 'well below' 2°C above the 'pre-industrial' (i.e., 1850-1900) level; indeed, hopefully the rise will be limited to just 1.5°C.

Yet the 'hard facts' of the past twenty years reveal a *very* different story. Thus, comparing world energy consumption—in exajoules (EJ)—in 2000 with the year 2019: global use of oil—still the

[1] Dyson (2005) uses 2000 as the base year and assembles many points and arguments which, quite intentionally, are not restated here. This is partly because the experience of the last two decades has generally borne them out. But it is also because the situation humanity confronts has moved on greatly in the space of only a few years—so much so that rather different issues must now be addressed. Note too that the present paper generally substitutes the more objective word 'heating' for the comfier word that is 'warming'.

leading primary energy source—grew by 25 percent (from 154 to 193 EJ); consumption of coal rose by a massive 60 percent (from 99 to 158 EJ); and natural gas grew by 64 percent (from 86 to 141 EJ).[2] Influenced by the 2011 disaster in Fukushima, the world's use of nuclear energy fell slightly (from 25.8 to 24.9 EJ). And there was sizeable growth for hydropower (from 26.5 to 37.6 EJ)—largely due to developments in China, including the completion of the Three Gorges Dam. Consumption of renewable energy—i.e., wind, solar, geothermal, and biomass— expanded rapidly (from 2.6 to 29 EJ). But in 2019 this category of power generation still only accounted for about 5 percent of total primary energy use. A key message from these figures is that, despite all of the hype, global use of fossil fuels—i.e., coal, oil, and natural gas—increased by 45 percent (from 339.5 to 492.3 EJ) in just nineteen years! The emissions from burning these fuels rose by a similar percentage—reaching 34.2 $GtCO_2$ in 2019 (the illustrative figure of 29.6 $GtCO_2$ mentioned above was surpassed in 2007) (British Petroleum 2020). Informing these developments, of course, was a 1.6 billion (i.e., 25 percent) rise in the world's population.

These *massive* increases in fossil fuel energy use have informed other alarming trends. In particular, between 2000 and 2019 the level of atmospheric CO_2—as gauged by the benchmark measurements made at the Mauna Loa Observatory in Hawaii—rose from 370 to 411 parts per million (ppm) (Tans and Keeling 2021). This too is a massive change in a very short period. The level of atmospheric CO_2 is obviously crucial in the context of the so-called 'greenhouse effect'. And perhaps the most important thing to know about the level of atmospheric CO_2 is that it has increased *every* year since 1959—the first full year for which there is a measurement (of 316 ppm). In effect, then, the level is continually being ratcheted upwards. The figure for 2020 was 414 ppm. And, inevitably, the figure for 2021 will be appreciably higher still. Even more disturbingly, as column (ii) of Table 1 clearly shows, the size of the average annual increment in atmospheric CO_2 has increased—i.e., there is an *acceleration*. Thus, during 2000-09 the average annual increment was +1.91 ppm per year; and for 2010-19 it was +2.40 ppm. The acceleration dates from the 1960s.[3]

For completeness, it should also be noted that the period 2000-19 also saw major rises in the levels of methane (CH_4) and nitrous oxide (N_2O) in the atmosphere (see Dlugokencky 2021a, 2001b). These are both important, if secondary, GHGs. In their cases too, the annual increments show little sign of slowing, and they are both being influenced upwards by, among other things, increased human activities (e.g., in agriculture) linked to population growth.

Table 1 Global atmospheric CO_2 concentrations and surface temperature anomaly estimates, 1990-2019

	CO_2 at Mauna Loa		Temperature HadCRUT4		Temperature GISTEMPv4	
Decade	Average annual level (ppm)	Average annual increment per decade	Average annual temp anomaly (°C)	Average annual change per decade (°C)	Average annual temp anomaly (°C)	Average annual change per decade (°C)
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
1990-99	360.46	+1.53	0.275	+0.019	0.383	+0.011
2000-09	378.58	+1.91	0.463	+0.020	0.591	+0.028
2010-19	400.21	+2.40	0.612	+0.023	0.807	+0.032

Notes: The CO_2 data are NOAA/GML measurements from Mauna Loa taken from Tans and Keeling (2021). HadCRUT4 temperature anomalies are relative to 1961-1990 and are taken from Morice et al. (2020). GISTEMPv4 temperature anomalies are relative to 1951-1980 and are from GISTEMP Team (2021).

[2] An exajoule is a unit of electrical energy equivalent to one quintillion joules. Using estimates for 2019 in these comparisons means that they are unaffected by the Covid-19 pandemic.

[3] The annual mean growth rate of atmospheric CO_2 has risen since the 1960s. However, in the 1990s there was a slight fall in the growth rate compared to the 1980s (Tans and Keeling 2021). The fall reflected especially low growth rates in 1992 and 1993 and was probably related to the volcanic eruption in 1991 of Mount Pinatubo in the Philippines.

Turning to the world's surface temperature (land and marine), as recently as 2014 deniers of global heating could refer back to 1998—an abnormally warm year—to prop up their claim that there was no increase in temperature.[4] However, estimates for subsequent years mean that this subterfuge is no longer feasible. In fact, the rise in temperature from around 1980 looks almost inexorable. Thus, and as expected, and as both the respected HadCRUT4 and GISTEMPv4 temperature anomaly series summarized in columns (iii) and (v) of Table 1 show, 2000-09 supplanted the 1990s as the warmest decade since direct measurements began; and 2010-19 then supplanted 2000-09. The year 2020 was the third hottest on record according to HadCRUT4, and joint equal hottest (with 2016) according to GISTEMPv4. Importantly, note that both of these standard global series suggest that the average annual temperature rise is *accelerating* (see columns (iv) and (vi)).[5] This may partly reflect a reduction of particulate matter in the atmosphere—leading to a decrease in negative atmospheric aerosol forcing (Hansen and Sato 2020). Nevertheless, it is a disturbing development which for some reason has been poorly articulated beyond the specialist scientific community.

In this context, the Paris Agreement's aim of limiting the global temperature increase to less than 2°C is surely unrealistic—especially given that a rise of around 1.1°C in temperature (over the pre-industrial level) is thought to have *already* taken place, and because during 2000-19 heating is estimated to have been occurring at average annual rates of +0.022°C (HadCRUT4) and +0.030°C (GISTEMPv4). Moreover, the Paris Agreement itself contains something of a deception. This is because it made no specific mention of the negative-emission technologies (NETs) which are required to achieve its aims. Thus, restricting the temperature rise to less than 2°C is actually based on the—unstated—assumption that NETs will be introduced on a huge scale later during the present century (Anderson 2015).[6] That this is indeed the case is now generally agreed (e.g., see IPCC 2018). Terms like 'magical thinking' and 'techno-utopia', have been used to describe the current state of NETs.

To conclude this section, the latest assessment report—AR6—of the Intergovernmental Panel on Climate Change (IPCC) states that '[c]limate change is already affecting every inhabited region across the globe with human influences contributing to many observed changes in weather and climate extremes' (IPCC 2021: 41). Moreover, and despite difficulties in measuring changes at the global level, AR6 finds clear evidence of a relatively recent acceleration in factors such as: overall levels of precipitation, the incidence of heavy rainfall events, the occurrence of heatwaves, the frequency of tropical cyclones, and the rate of world sea level rise (IPCC 2021: 7-12).

With this as background, and adopting a specifically *demographic* lens, the paper now considers the implications of global heating for the future.

The Future

Perhaps the first thing to say about future population prospects and climate change is that by various demographic criteria seemingly distant dates—such as the end of the current century—are actually

[4] The occurrence of a major El Niño/Southern Oscillation—which involves considerable ocean surface warming—contributed to the (then) record temperature recorded for 1998. Of course, unlike the level of atmospheric CO_2, global temperatures do go up and down from year to year, though on a distinctly rising trend.
[5] The HadCRUT4 anomaly series are produced by the UK Met Office in association with the Climate Research Unit at the University of East Anglia; the GISTEMPv4 series are produced by the Goddard Institute for Space Studies which is affiliated with the Earth Institute at Columbia University. The National Climatic Data Center in the United States also produces global temperature estimates and related anomalies. They too suggest an acceleration, but because they employ a very long reference period (1901-2000) they are not shown here.
[6] Biomass energy carbon capture and storage is one prominent NET (Anderson 2015). For other potential approaches to GHG removal from the atmosphere, see Harthan and Lindley (2021).

fairly close. By way of illustration: given current world mortality conditions, more than 90 percent of children born in 2021 will be alive in 2050, and over 40 percent will survive to 2100.[7] Indeed, even the year 2200 lies well within the compass of two overlapping, if long, lifetimes.

Until now, population growth has been the second most important factor contributing to the rise in CO_2 (and other GHG) emissions—second only to economic growth with its hitherto heavy reliance on burning fossil fuels (e.g., see Bongaarts 1992; Cohen 2010). Between 2020 and 2050 population growth will have a significant—though diminishing—influence on global CO_2 emissions, which at some point within that period are expected to peak and then start to fall.

In this context, the United Nations projects with reasonable confidence that between 2020 and 2050 the world's population will grow by approximately 2 billion. However, two major emitting regions—most crucially East Asia (including China which alone accounted for 28 percent of world CO_2 emissions in 2019), but also Europe (responsible for about 9 percent of emissions)—are projected to experience slight population declines (of *c.* 4-5 percent).[8] This signals a coming era in which regional population declines will contribute—albeit only modestly—to regional reductions in CO_2 emissions. In Europe, a fall in total emissions has been occurring since about 2007 (although this partly reflects the 'export' of industrial production, notably to China).[9] In East Asia, however, a fall in overall CO_2 emissions appears to be at least a decade away; what actually happens in this region will depend greatly upon what happens in China—about which there is considerable uncertainty. The UN projects fairly limited population growth over 2020-50 for Latin America (17 percent), Southeast Asia (19 percent), and South-central Asia (24 percent). There is evidence that a fall in CO_2 emissions has been occurring in Latin America since about 2014; therefore, the effect of future population growth in this region may only be to slow the rate of the fall. For Southeast Asia and South-central Asia, it seems likely that future demographic growth will initially contribute to a further rise in emissions before then—slightly—slowing a fall. That said, especially in South-central Asia any peak in emissions is likely to occur rather late in the period 2020-50. This is because in India (responsible for about 7 percent of global CO_2 emissions) the level of per capita emissions, at only 1.8 tons per person, is still exceptionally low.

North America ranks second only to East Asia in terms of total CO_2 emissions. By itself, the United States accounts for about 14 percent of global CO_2 emissions and it also has a very high level gauged on a per capita basis—of around 15.3 tons per person. North America is likely to be the region where population growth—projected at 56 million (i.e., 15 percent) for 2020-50—will have the largest effect on global emissions (reflecting the very high per capita level). However, this effect will work through slowing an already established fall in emissions rather than in contributing to a rise (overall CO_2 emissions in the US have been decreasing since around 2007). Finally, slightly more than half the projected population growth of 2 billion for 2020-50 relates to Africa, a region that only accounts for 4 percent of global CO_2 emissions. Africa's average level of per capita emissions—at about 1.1 tons per person—is, and will doubtless, remain very low. Consequently, the impact of future population growth on CO_2 emissions in this region—while sizeable in percentage terms—will be fairly minor in the global context.

Turning to the level of atmospheric CO_2 and the Earth's surface temperature, it is almost certain that there will be significant increases in both. The effect of an increase in the former on the latter is

[7] United Nations (2019) is the source for the population estimates and projections used in this paper.
[8] In this paragraph and the next, the broad statements regarding future levels of CO_2 emissions are informed by statistics on past trends from OWID (2021) and illustrative projections to 2030 in Climate Action Tracker (2021). The CO_2 emissions data exclude emissions from land use changes and cement production. The regions discussed cover about 96 percent of the world's population. Statements on current regional contributions to overall carbon emissions and per capita emission levels relate to 2019.
[9] The statement about the fall in Europe excludes Russia where overall CO_2 emissions have been roughly constant since about 2000.

usually assessed in terms of a doubling of atmospheric CO_2 over the pre-industrial level. This means an increase from around 280 ppm to about 560 ppm. The standard view has long been that such a doubling would, with a lag, lead to a temperature rise of 1.5-4.5°C (central figure 3°C, National Research Council 1979). But given the estimated 1.1°C of heating that has already taken place, and the future heating that is currently committed in the climate system (perhaps at least +0.3°C) the lower end of the 1.5-4.5°C range is now regarded as unlikely. Research generally results in central estimates of between 3°C and 4°C. An influential recent study concludes that there is a two-thirds chance of the figure lying between 2.6°C and 3.9°C (Sherwood et al. 2020).

Against this background, it appears likely that the level of atmospheric CO_2 will reach 560 ppm before or around the year 2100. Thus, assuming the continuation of annual rises of +1.91 and +2.40 ppm (as per 2000-09 and 2010-19 in Table 1) would lead to 560 ppm being reached in the years 2098 and 2082 respectively. However, assuming a rise of +2.90 ppm (to make a modest allowance for some future acceleration) would mean that it was attained as early as 2071.[10] It is worth noting that having reached 414 ppm in 2020 we are already almost half-way to a doubling of atmospheric CO_2. In relation to the world's surface temperature, a continuation of the average annual rises for 2000-19 of +0.022°C (HadCRUT4) and +0.030°C (GISTEMPv4) would lead to 2°C being reached around 2060 and 2050 respectively. And if these average annual rises continued then by 2100 the corresponding figures would be 3°C and 3.5°C. Of course, these illustrative calculations make no allowance for any speeding up of the temperature increase.

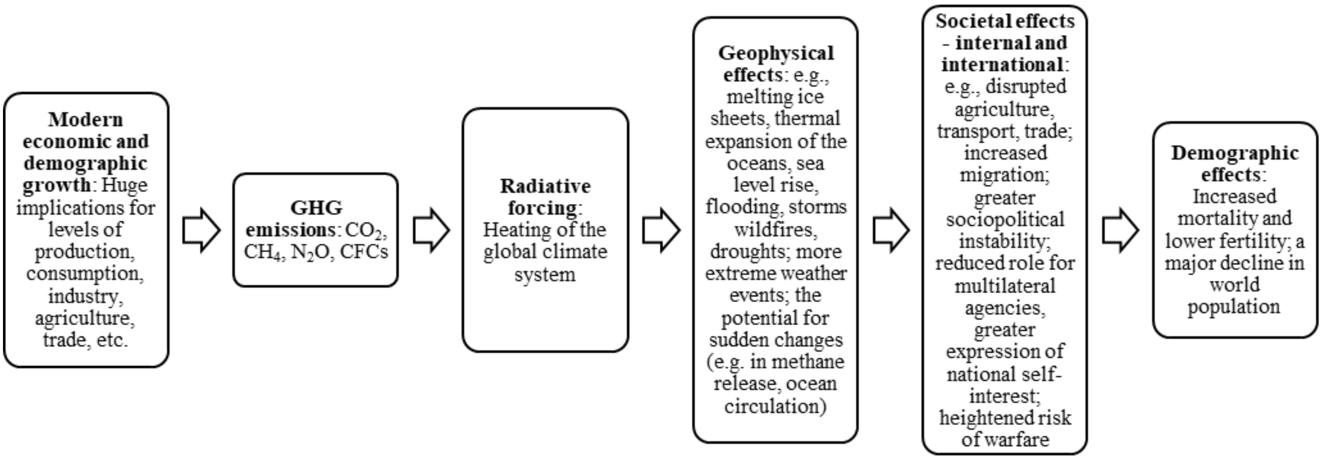
These sorts of temperature rise for this century—let alone the next—suggest strongly that the future will become increasingly dire. A multitude of warnings illustrate this. For instance, Petteri Taalas, the Secretary General of the World Meteorological Organization, recently remarked that '[o]n the current path of carbon dioxide emissions, we are heading towards a temperature increase of 3 to 5 degrees Celsius by the end of the century'. The latest AR6 report of the IPCC refers to climate change as being widespread, rapid, and intensifying, and states that many of the attendant changes that are now underway are likely to be irreversible (IPCC 2021). Further, ahead of the COP26 get-together in Glasgow, the UN Secretary General Antonio Guterres has warned repeatedly that humanity is on course for a 'climate catastrophe' with terrible wildfires, floods, cyclones and hurricanes becoming the 'new normal'. This is 'dangerous' climate change. To avoid such a bleak scenario would have required taking *much* greater action *much* earlier. It is unsurprising, then, that there are more and more ominous forecasts about what lies ahead (e.g., see Anderson and Bows 2011, Wallace-Wells 2019, Gilding 2019). Even on the—highly unlikely—basis that there are reductions in CO_2 emissions in line with the Paris Agreement, it is still quite possible that the Earth's system has already been sufficiently destabilized to lead to a temperature rise of 4°C with huge, if lagged, increases in sea-level. What appear to be underway are various geophysical 'cascades'—in which particular processes (e.g., the retreat of mountain glaciers, summer sea-ice loss) trigger other processes (e.g., forest dieback, raised oceanic bacterial respiration) and, in turn, still more processes (e.g., permafrost thaw, release of CH_4 from ocean floors, etc.) (see Steffen et al. 2018).

Against this backcloth, Figure 1 presents a simple general model with selected key linkages. Thus, beginning in the decades around 1800, a combination of modern economic growth and population growth (resulting from the global demographic transition) has underpinned massive rises in CO_2 and other GHG emissions and, therefore, changes in the composition of the atmosphere—leading to radiative forcing and global heating. In turn, the heating is having geophysical effects—e.g., flooding, heatwaves, extreme weather events, etc.—some of which—e.g., the loss of ice sheets and glaciers, and increased release of CO_2 from forest fires—contribute to yet further heating in a self-reinforcing way. In turn, geophysical processes have societal effects which operate both internally and

[10] In the context of this acceleration, there are increasing signs that the capacity of the world's oceans, soils, and terrestrial vegetation to absorb CO_2 is declining. See, for example, Gatti et al. (2021).

internationally. The societal effects include, for example, disruption of food supplies, price rises, reduced living standards, migration, socio-political instability, and conflict. Finally, there are demographic effects which, at the global level, work through mortality and fertility.

Figure 1 Selected linkages between modern economic and demographic expansion, environmental and societal consequences, and population decline



The initial causal processes in Figure 1—i.e., modern economic growth and demographic transition—began roughly two hundred years ago. But in terms of their occurrence, and their effects, they have mostly been *much* more recent. In particular, both processes have escalated hugely in the period since World War II. To illustrate this, in the space of just the seventy-years from 1950 to 2020: the human population grew from 2.5 to 8 billion, an increase of about 220 percent (United Nations 2019); the average level of GDP per capita for the world, taken as a crude measure of material consumption, rose from about $3,300 to $15,200, an increase of around 360 percent (Bolt and van Zanden 2020); and annual CO_2 emissions grew from 6 to about 36.4 billion tons, a rise of approximately 500 percent (OWID 2021). Moreover, it is essentially in this same short time period that the level of atmospheric CO_2 has been destabilized. In 1950 the level was still only around 309 ppm i.e., not much above the preindustrial figure of *c*. 280 ppm. Today, as noted, it exceeds 414 ppm and is rising relentlessly.[11]

It is in this context that all of the previously-mentioned signs of *acceleration* (e.g., in atmospheric CO_2 and resulting geophysical processes) become even more disturbing. In brief, a huge amount has happened in a very short period of time. One implication of this may be that we have lost any capacity to significantly influence trends, let alone 'control' them.[12] And, of course, this comes on top of the fact that the changes needed to decarbonise any society are incredibly difficult; that avoidance and denial continue; and that, everywhere, political institutions are simply not up to the task of transforming societies at anywhere near the necessary rate.[13] Furthermore, there is of course

[11] Dollars are in 2011 prices. The global CO_2 emission figures cited here differ slightly from those used elsewhere in the paper because they include emissions from the manufacture of cement. The figure for atmospheric CO_2 of 309 ppm for 1950 results from back-projecting from the measurement for 1959 (316 ppm) on the basis of the average annual increment for the period 1959-68 (0.8 ppm). For the data see Tans and Keeling (2021).

[12] See, for example, the considerations mentioned in footnote 10.

[13] A recent study by Anderson, Broderick and Stoddard (2020) shows that Sweden and the UK, countries which like to see themselves as 'climate progressive', fall far short of what is required for the Paris Agreement. Relatedly, everywhere, the politicians in power change, which can lead to major turnarounds in policies.

appreciable *momentum* in demographic, economic, social, political, and climate processes—all of which would need to be overcome.[14]

These things said, there is currently no clear evidence that global heating is having significant demographic effects at the global level. For instance, mortality in most countries has been declining for decades. And there are many ways in which further declines can be achieved. Also, statistics from the International Disaster Database suggest that there has been a major long-term fall in 'climate-related' deaths—i.e., those specifically caused by floods, droughts, storms, wildfires, and heatwaves; moreover, in some places the temperature rises experienced so far have probably had beneficial effects, for example in reducing deaths due to the occurrence of milder winters (see Lomborg 2020). Nevertheless, the lack of evidence that heating is having adverse mortality effects may partly be because, as in other respects, there is substantial momentum to the process of mortality decline; and it may also reflect the fact that most of the global temperature rise—and acceleration—has been quite recent (i.e., since the 1980s). Furthermore, the main ways in which it is thought that global heating may slow the pace of mortality decline, and indeed begin to generate rises, do *not* pertain to individual events like floods, storms, and heatwaves. Rather, as is implied in Figure 1, they relate to larger processes which over various timescales contribute to, and result from, wider societal disruption (e.g., loss of cultivatable land, flooding of cities, food shortages, socio-political instability, etc.). In short, due to such factors *cascades* of adverse events can—and do—occur in the socio-political realm. And they can be unexpected and sudden. In this respect, most early accounts of the civil war in Syria, which began in 2011, were understandably framed in terms of *pre-existing* social and political circumstances. There was little mention of the preceding lengthy and severe drought—which may have partly resulted from climate change. Subsequently, however, there has been discussion of whether factors related to global heating played a part in the genesis of the conflict—something which certainly cannot be discounted (e.g., see Kelley 2015, Selby et al. 2017).

Several further considerations are worth noting here. Most obviously, perhaps, the crisis in Syria illustrates the capacity for heightened migration (both internal and international). On a wider canvas, it is clear that pre-existing circumstances (political, religious, socioeconomic, etc) mean that there are *potential* conflicts in many places around the world, and that it may only need a small change to set them off. In such locations, heating may well act as a *remote* causal force—and consequently remain generally unnoticed. Moreover, especially in the interconnected modern world, the links between climate change and societal disruption are likely to be extremely complex.[15] For instance, it has been argued that socio-political disruption in the Middle East around the year 2011 was influenced by unusual climate events in places as distant as Australia and China (Sternberg 2013).

Finally, while mortality and migration receive most attention in relation to future developments, history strongly suggests that the fertility response to global heating will probably be *at least* as significant. In this context, there is already evidence that 'climate anxiety' is influencing attitudes towards childbearing in low fertility countries. This anxiety reflects concern about the state of the world in which any child will grow up and have to live. But it also reflects concern about the environmental damage that a child is likely to contribute during the course of their lifetime (e.g., see Schneider-Mayerson and Ling 2020, Arnocky et al. 2012). Beyond these issues, lower fertility—compared to what would otherwise prevail—is likely to result from intensified levels of economic and other stress. And it can also be expected to result from conditions of upheaval and conflict.

[14] Such issues are not discussed any further here, although they are touched on in Dyson (2005).
[15] Interconnectedness and specialization, so often portrayed as strengths, can also be two-edged characteristics. Relatedly, 'just in time' supply procedures and low stock levels are also potential sources of heightened vulnerability.

Discussion

It is difficult to look at the geophysical trends and see anything but troubled times ahead. There is considerable uncertainty, of course. And many politicians, in particular, will continue to claim that the task of cutting emissions at the required rates is still feasible. However, the view taken here is that stated succinctly by Clive Ponting (2007: 408), namely that 'the underlying economic and social forces that have dominated the world in the last two hundred years are simply too strong to be altered in the decisive way that would be needed to make the sort of reductions in carbon dioxide output that climate scientists regard as essential if catastrophe is to be avoided'. Accordingly, the likely general implications of our current situation must be faced, including in the field of demography.

That said, history provides no direct portents for contemplating the demographic future. Of course, changes in climate have had profound implications for population trends in the past. For example, the warming that ended the last glacial period laid the basis for the rise of agriculture and the occurrence of what is often termed the 'first demographic transition' (e.g., see Coale 1974, Bocqet-Appel, 2011). There are also reasons to think that global temperature fluctuations do much to explain the striking synchronicity of population trends which has prevailed at either end of the Eurasian land mass during most of recorded history (e.g., see McEvedy and Jones 1978, Galloway 1986). Again, the occurrence of an extremely cold period in the mid-seventeenth century, related to low sunspot activity, appears to have led to the demise of a substantial fraction of humankind (Parker 2013: xxvii). Other illustrations can be provided.[16] However, in most cases they relate to fairly small variations in temperature in which colder periods were more difficult and warmer periods were more benign. In short, when thinking about the effects of, say, a 3-4°C temperature rise by the end of the present century, we are entering largely uncharted terrain.

Hitherto demographers have chiefly been concerned with assessing the contribution of various forms of population change to increases in CO_2 emissions. As noted, population growth has emerged as the main factor here, with compositional changes, like ageing and urbanization, being secondary. Inevitably, consideration of the role that global heating may play in the demographic future has been limited and somewhat speculative. That said, one area of research has involved identifying groups who might be forced to migrate—such as 'climate change refugees' from small low-lying island states (e.g., see Wyett 2014, Thomas and Benjamin 2018). On a wider canvas, the Stern Review (2007) thought that by 2050 at least 200 million people might be permanently displaced by a mixture of rising sea levels, increased flooding, and greater desertification. Similarly, the World Health Organization (2018) considers that between 2030 and 2050 there may be an extra 250,000 excess deaths each year due to climate-related increases in malnutrition, malaria, diarrhoea, and heat stress. That said, if the world's temperature gets hotter along the lines that have been discussed in this paper, then such notional numbers are likely to be very much on the low side for the period after 2050. It is notable too that research which tries to relate impending temperature increases to numbers of deaths is almost always based on the assumption of a smooth trajectory into the future. But there are many ways in which future heating may well entail really major *discontinuities*—societal as well as geophysical.[17]

Turning to population projections, the subject of global heating and climate change has received relatively little attention. For example, a series of essays written by demographers to accompany publication of the UN's long-range population projections out to the year 2300 makes almost no mention of the subject; and the same applies for later regular UN biennial projections which extend to 2100 (United Nations 2004, 2020). Using a probabilistic approach, current UN population projections

[16] Of course, cases of demographic decline are often the outcome of other kinds of environmental over-extension (e.g., see, Ponting 1991, Diamond 2006).
[17] Geophysical possibilities here include accelerated ice sheet melting, large-scale methane release, and a collapse of the thermohaline circulation system in the world's oceans.

mostly incorporate a ‘normal’ mortality variant trajectory which *inter alia* reflects the ‘*historical* variability of changes’ (emphasis added, United Nations 2019). Of course, any incorporation of the potential future effects of global heating can only be illustrative. Nevertheless, one suggestion might be to combine a (new) high mortality variant with a low fertility variant within the UN’s regular projections.[18] A welcome move here is provided by the illustrative projections of KC and Lutz (2014). In the most extreme case, these projections incorporate a massive mortality disaster (during 2025-30) in which 10 percent of the entire human population dies. But because it is a one-off calamity, subsequently an essentially normal population growth trajectory is, unsurprisingly, resumed. On the present view, however, a case can be made for projections incorporating scenarios in which there are recurrent adverse events—i.e., *cascades*—geophysical, socio-political, and demographic.

The UN’s current medium variant projection is that between 2020 and 2050 the world’s population will grow by about two billion—with an additional one billion people projected for 2050-2100. However, in 2050 the world’s population will only be growing at about 0.5 percent per year. Indeed, besides sub-Saharan Africa, all world regions are projected to be experiencing growth that is either negative or near-zero. Accordingly, for most of humanity, relative to the projection, it will only take a small additional fall in the birth rate, and/or rise in the death rate, to bring about—or in some regions amplify—circumstances of population decline. Indeed, by 2050 even sub-Saharan Africa’s population may be smaller than is currently projected. In sum, if global heating continues at its current pace, the world’s population may start to decline significantly earlier—and faster—than the UN currently envisages.[19] The additional one billion people projected for 2050-2100 seems especially questionable; and, in this context, the heightened uncertainty brought about by the fact of global heating might at least be mentioned. Otherwise, the UN’s population projections run the risk of, to borrow the palaeontologist Richard Fortey’s words, exemplifying the ‘kind of optimism built into our species that seems to prefer to live in the comfortable present rather than confront the possibility of destruction’ (see Parker 2013: xv).

In conclusion, the global demographic transition occurred over a period of very roughly 250 years—from the late eighteenth century to (it seems likely) the second half of the twenty-first century. During this time the world’s population will have grown by roughly a factor of ten. This growth in human numbers has contributed significantly, if remotely, to global heating; and the fact of *past* population growth continues to have a lasting influence through the unprecedented size of the *current* world population. Looking ahead, population growth in itself is set to have a fast-diminishing influence on global heating. But given recent accelerating geophysical trends, a reverse influence—i.e., from heating to human numbers—now looks highly likely.

[18] Whereas for fertility there are high and low variants, for mortality there are only the normal and constant variants.

[19] At present, even the 95 percent lower confidence interval around the UN’s medium variant projection suggests little reduction in the world’s population during 2050-2100.

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