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DEBATE

Overshooting global warming and overshooting fertility decline. Beyond the smooth stabilization paradigm

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ABSTRACT Our thinking about future trends in both population and climate change has traditionally been dominated by the view of smooth trajectories towards ultimate stabilization. But reality turns out to be different: climate warming will not stop at the Paris goal of 1.5 degrees Celsius, but is expected to overshoot, and will therefore need to be addressed through negative emissions (taking carbon out of the atmosphere) later in the century; similarly, fertility decline has not stopped at the replacement level, and instead seems to be falling to lower and lower levels, with nobody knowing when it will stop and whether there will be an upturn. In both cases, societies will need to adapt to rather extreme discontinuities, rather than being able to count on smooth stabilization. Furthermore, the reality that climate change overshooting will require serious mitigative action during the second half of this century brings alternative demographic trends back into the picture as potentially relevant factors in mitigation, since alternative fertility and education trends in the near future will take decades to be reflected in changing population sizes and structures, including in human capital.

KEYWORDS Climate change • Fertility decline • Stabilization • Overshooting • Mitigation • Adaptation

Assumed global convergence in fertility and climate stabilization

Over the past decades, our thinking about the long-term future of humanity has been dominated by envisioning smooth changes that would eventually lead to a new equilibrium – based on the assumption of constant components – even when contemporary conditions are far from stable. This paradigm has been most explicitly enshrined in the UN world population projections, which have been produced on a regular basis since the 1950s. Even during periods when some countries still had fertility levels of more than six children per woman, these projections assumed that fertility in all countries in the world would eventually converge to the so-called replacement level (Keilman, 1999). Together with the assumption that life expectancies would also converge to a maximum level – which was assumed to lie at around 75 years in the 1960s (Oeppen & Vaupel, 2002) – this perspective

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resulted in an image of the future in which all countries in the world would have similar fertility and mortality levels. As it was also assumed that international migration would disappear, this implied that all countries would eventually have constant population sizes and age structures. Thus, this paradigm projected a vision of eternal demographic stability once countries have passed through the temporary disruptions caused by demographic transition.

This vision of the demographic future was convenient in several ways. It was easier for the producers of population projections to simply assume that the populations of all countries would converge to certain levels than it was to define and justify divergent trajectories of fertility, mortality and migration based on specific numerical assumptions for each population. This vision was also politically convenient in the context of the United Nations, because it meant that no member country would have to be afraid of continued exponential population growth or even population decline. Although reality turned out to be quite different and some adjustments in projection assumptions became inevitable over time, the basic concept of convergence to some equilibrium is still dominant in our thinking about future population in the longer run.

In the climate change research community, a similar equilibrium thinking dominated after the topic became prominent in the 1970s. As late as 1978, the IIASA Workshop on Carbon Dioxide, Climate and Society – one of the first international assessments of the climate problem – concluded that a prudent energy policy would be to maintain flexibility because scientific knowledge of the climate system and the carbon cycle was still too limited (Lutz et al., 2023). Since then, our knowledge of the climate system has vastly improved, and the scenarios that were developed to describe the pathways quantitatively tended to assume alternative smooth trajectories over the longer run (Nakicenovic & Swart, 2000). More recently, the community's thinking became increasingly dominated by the postulated need to avoid the crossing of a fixed "planetary boundary", which, if transgressed, would push the world over the cliff of moving beyond the Holocene climate equilibrium that had facilitated the development of human civilization over the past 10 thousand years. Due to assumed tipping points, the possible crossing of this safe boundary – which is, according to the Paris goals, set at global mean temperature change of 1.5 or a maximum of 2.0 degrees centigrade – has been associated with the likely end of human civilization on this planet (Rees, 2004). As a consequence, most scenarios are focused on the near-term reductions in emissions that would asymptotically approach these defined maxima in the long run. Only very recently, when it became evident that reaching the Paris targets is unlikely, the idea of future negative emissions that would bring the world back from beyond the cliff has become a serious topic of analysis.

This change in paradigm from the assumption of reaching an equilibrium to the conceptualization of overshooting followed by recovery also has significant consequences for our thinking about the relationship between population and climate change mitigation. If we only consider the goal of reaching net zero emissions by 2040 (for the EU) or 2050 (for the world), then the contributions of demographic trends to climate change mitigation can only be modest due to the great inertia of demographic change: changes in the birth rate over the coming years will hardly affect the size of the adult population over the next 15-25 years. If, however, it becomes necessary to recover from overshooting global warming, mitigative action will continue into the second half of the century, and the

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possible contributions of demographic changes to such late mitigation efforts may become much more important.

In the following, I will briefly highlight some new research on overshooting climate change and overshooting fertility decline. Then, I will look at their relationship by revisiting the influential I = PAT approach, which has dominated the discussion since the 1960s.

To address the question posed in this debate session, this commentary will focus only on population and climate change mitigation, for which the role of demography has been less evident than in the case of adaptation, for which the important role of changing population and human capital has already been clearly demonstrated (Lutz & Muttarak, 2017).

Overshooting the Paris goal of 1.5 degrees Celsius

Global warming is very likely to pass the goal of 1.5 degrees Celsius, largely owing to low institutional capacity. This is one of the conclusions of a recent major international study led by IIASA and involving over 20 research groups from around the world, on which this section will heavily draw (Riahi et al., 2021; van Ruijven et al., 2023). This study also builds on many parts on the IPCC Sixth Assessment Report (IPCC, 2023), and investigates the feasibility of different decarbonization pathways. The study concludes that neither current policies nor existing nationally determined contributions (NDCs) come close to meeting the Paris goals.

There are many not unlikely scenarios in which global warming overshoots even the more modest 2.0 degrees Celsius goal, which is expected to result in significant climate discontinuities, possibly triggering irreversible tipping mechanisms. But even when we limit the analysis to the more optimistic case that temperatures can be kept below 2.0 degrees by the end of century, there are different possible pathways, some with and some without temporary overshooting. Figure 1, which is taken from the abovementioned study, shows the pathways of global carbon emissions for around 100 different scenarios calculated on the basis of a range of different Integrated Assessment Models (IAMs). The grey lines at the top show pathways that follow current national policies until 2030 (NDC), which put the 1.5 degrees target completely out of reach, because the late start makes it virtually impossible to scale up decarbonization quickly enough. The rest of the pathways are grouped into two different families of scenarios: the blue ones do not allow peak temperatures to be reached over the course of the century, and thus require faster near-term declines in emissions, while the red ones focus only on temperature at the end of the century, and thus allow for temporary peaks and compensation through negative emissions later in the century. Such negative emissions would be based on actively taking carbon out of the atmosphere using technologies that currently are not feasible at scale.

While this is not the place to discuss these scenarios in any detail, the important insight for this commentary is that particularly under the red scenarios that include the possibility of negative emissions towards the end of the century, mitigation continues to matter for many decades into the future. In other words, while the blue lines must decline to very low emissions levels already during the first half of the century, virtually all red lines continue to decline during the second half of the century, thus pointing to a different time horizon for

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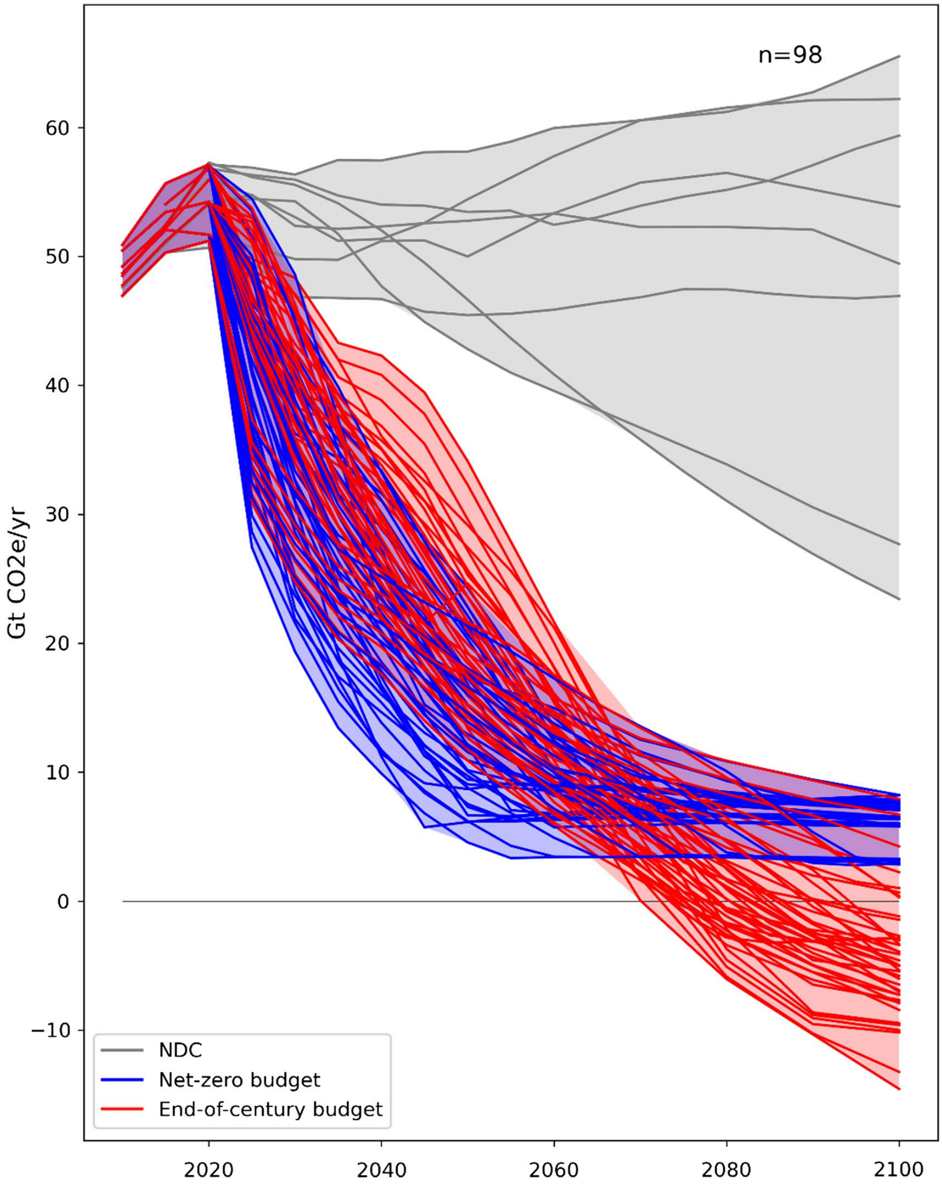
Figure 1 Global emissions scenarios where warming is 2 degrees Celsius or below



Source: van Ruijven et al. (2023) (CC BY-NC 4.0)

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mitigation under the temporary overshooting scenarios. This second case brings mitigation needs back into the time horizon in which alternative demographic scenarios could make a major difference.

One further important conclusion of this study is that reductions in energy demand are particularly important to help reduce temperatures after a possible peak. Since future energy demands can be meaningfully associated with future demographic trends, this new focus on reductions in demand after overshooting opens up a new field of necessary research on the links between different demographic scenarios and climate change mitigation.

Overshooting fertility decline

As indicated in the introduction to this commentary, the notion of replacement fertility is still used as a major reference point in scientific analyses of fertility trends in both scholarly publications and the media. This is despite the fact that it is a rather technical concept derived from stationary population theory, and that under normal conditions, it does not result in constant population sizes of any real populations. Only under the artificial assumptions of no changes in mortality conditions, no migration and a stable population age structure does this concept lead to stationarity in the long run. Nevertheless, demographers and the general public alike seem to have a powerful intuition that if fertility is at or near replacement level, things are fine, but that if it is far below this level, then there is something fundamentally wrong.

This intuition based on long-term stable fertility levels may also be behind the rather alarmist recent media reports about low fertility. The news is currently full of reports about new record low fertility in different countries in East Asia or Europe, and about faster than expected fertility declines around the world (Bhattacharjee et al., 2024). These news reports are often accompanied by apocalyptic projections of the longer-term consequences of such low or ultra-low levels of reproduction. The situation is considered particularly dramatic in South Korea, where the period total fertility rate has fallen to around 0.7 children per woman, which is only one third of the abovementioned replacement level fertility. In a high-level meeting on fertility in Seoul in June 2023 – in which the author participated – the Prime Minster of South Korea even talked about the "extinction" of the Korean population unless dramatic steps are taken soon (MunhwaFutureReport, 2023).

Fertility-related concerns are also on the rise in many European countries, particularly those in the eastern part of the continent, where populations are already on a declining trajectory due to the combination of low fertility and outmigration. Another recent trend that challenges presumably established wisdom is the recent fertility decline observed in the Nordic countries, which used to have fertility well above the European average, presumably due to the easy compatibility of work and family. In this context, the worries expressed are again based on the assumption that these currently observed low fertility levels are here to stay. These levels may well persist, as long as they are not merely the result of tempo effects, i.e., a temporary depression of period fertility rates due to postponement of childbearing. Indeed, it appears that in many countries, cohort fertility has also reached very low levels. Whether fertility will continue to decline or will recover is unclear at this point.

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There is very little scientific analysis about how low fertility can or will fall. One exception is the brave attempt by Antonio Golini in 1998 (Golini, 1998), in which he estimates possible minimum cohort and period fertility levels using certain assumptions that are based on exceptionally low fertility conditions in specific past populations. He comes up with a minimum cohort fertility of 0.7-0.8 children based on the assumption that 20-30 per cent of women remain childless and the rest have just one child. But it is not clear whether the future could bring different conditions in which fertility levels are even lower. What is clear is that none of the established explanations of fertility declines in the past can help to predict future fertility trends once they have reached very low levels. As I have argued in an earlier commentary (Lutz, 2020), female education – which has been a main driver of fertility decline in the past – is still likely to empower women to reach the family size they find desirable, but what this desired family size will be in the future and how it competes with other desires in life are questions for which we have little theoretical or empirical basis. Such questions must now be addressed in the realm of changing cultures and the moods and priorities of the younger generation, about which we can only speculate.

The conclusion from the above discussion about the future of low fertility, which is relevant to the main topic of this commentary, is that given the current state of very limited knowledge about the future of fertility – i.e., about whether it will continue to fall to levels well below 1.0 or will recover to some extent – there is no reason to assume the existence of long-term trends that are constant or that asymptotically reach a certain level. We may as well consider different scenarios of future ups and downs in fertility levels or long-term swings. Thus, there may be an overshooting of fertility decline, followed by some degree of recovery. Actually, judging from past experience, long periods of constant fertility have been rare exceptions, with rather strong fluctuations being the norm, even though the overall trend has been downwards. This observation should also have implications for the way we choose to make population projections in the future, irrespective of whether they are stochastic or based on alternative scenario assumptions.

Revisiting and modifying I = PAT

Finally, with respect to the implications of such uncertain future population trajectories for climate change mitigation, we may also have to revisit the long-established I = PAT approach, and modify it in the light of this new discussion of the overshooting of both climate change and fertility decline. Introduced by Paul Ehrlich and John Holdren in 1971 (Ehrlich & Holdren, 1971), the I = PAT identity offers a simple decomposition framework in which environmental impact (I), such as total carbon emissions, can be seen as the product of total population size (P), affluence (A) measured as GDP/P and technology (T) measured as emissions per unit of GDP (I/GDP). While this is a useful first approach to show that changes in population size do not translate 1:1 into total carbon emissions, and that other factors, such as A and T, matter as well, this approach also has many limitations that have been described in the literature. The first and so far only comprehensive book on population and climate change (O'Neill et al., 2001) already pointed at several of these problems. One issue is that it is not self-evident that individual members of the population

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should be seen as the basic units emitting carbon. Since many sources of emissions tend to be household-specific – such as heating, refrigerators and even car use – rather than directly proportional to the number of people in a household, alternative I = HAT specifications (where H stands for households rather than population) yield very different results with respect to the contributions of the demographic factor considered, because a decline in the number of children does not necessarily reduce the number of households. Another complication is that there are many interdependencies between the factors P, A and T that do not allow their impacts to be assessed independently. Later studies by O'Neill and collaborators have also shown that there are important missing variables in this specification – such as urbanization and education – that significantly affect the relationship between demographic change and climate change mitigation, and should thus be taken into account (O'Neill et al., 2010).

In the context of expected population declines and the need for negative emissions to counteract climate overshooting, the appropriate analytical models to assess the possible role of demographic variables in mitigation still need to be designed. O'Neill et al. (2001) already pointed at the "offset problem" in the simple I = PAT model, making it virtually impossible to allocate relative contributions to the different factors when they move in different directions, and thus partially offset the impacts caused by other factors. In the context of overshooting and assumed fluctuations among a more complex and interacting set of factors, new models need to be developed to appropriately identify the possible contributions of demographic trends. These new models also need to give appropriate attention to spatial and socio-economic heterogeneity.

In a nutshell, while the need to counteract likely climate overshooting through negative emissions during the second half of the century can be expected to make alternative demographic trends in this more distant future a relevant factor in humanity's efforts to stabilize the climate below 2 degrees Celsius, developing a more specific understanding of these interactions will require new analytical tools and new research strategies. This implies the need for a significant new research effort in which demographers can make an important policy-relevant contribution to help humanity mitigate one of its greatest future threats.

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