LETTER

Reply to O'Neill et al. and O'Sullivan: Fertility reduction will help, but only in the long term

O'Neill et al. (1) and O'Sullivan (2) argue that the results of our global population scenarios (3) are not credible. Here we demonstrate that their arguments are peripheral and that our conclusions are robust.

Both O'Neill et al. (1) and O'Sullivan (2) overlook that the demographic rates we used were not raw, global averages. O'Neill et al.'s (1) claim that our model "treats all people in the world as identical" is incorrect. Instead, we applied population size-weighted averages of the rates across the 14 WHO-CHOICE regions (www.who.int/choice). Thus, both the survival and fertility rates we used for the global projections reflect regional demographic trends. To demonstrate why this is essential, the example of Nigeria (1) is telling. Treating this country independently would yield an implausible projection of nearly 2 billion Nigerians by 2100 (175 million people today at 2.8% annual growth).

O'Sullivan's (2) recommendation that we should have used country-specific demographic data suggests a lack of awareness of the state of demographic datasets. For example, many countries, especially large-population developing nations, report no age-specific (yearly) vital rates. Even if such data existed, it would be an assumption-laden exercise to link each country's projection to all others via cross-migration. As we mention in our paper (3), migration remains one of the most difficult parameters to forecast for the future human population (4).

As O'Neill et al. (1) point out, had we not accounted for regional variation in demographic rates via the weighting procedure, the projected population size would have been around 20 billion (1, 5). In fact, our business-as-usual deterministic projection to 2100 (10.4 billion; see figure 1*A* in ref. 3) closely matched the median of 10.9 billion predicted by the United Nations (5) and falls within the revised range projected by one of the commenter's (P.G. of the letter in ref. 1) own models (9.6–12.3 billion) (6). Clearly, our baseline models are therefore as realistic as any existing demographic model for the aggregate global human population.

O'Sullivan's (2) critique that our regional sums are greater than the global model's projections is irrelevant because it ignores the weightings; it is a demographic tautology that the regional sums will exceed the aggregate (weighted) model's projection. As we emphasize in our paper (3), the purpose of the regional projections was merely to provide a relative rank for those areas of the Earth where biodiversity would likely be most threatened, as indicated by human population pressures on global Biodiversity Hotspots (7).

More importantly, both O'Neill et al. (1) and O'Sullivan (2) disregarded our statement that the scenarios were not intended to predict total population size. Rather, our principal goal was to test the sensitivity of human population projections to adjustments in fertility and survival through various "storylines." In other words, the final population sizes that arise from our models, although realistic in comparison with existing projections, are not predictions; they are instead principally useful as comparative demographic futures. As such, O'Neill et al.'s (1) complaint that our scenarios are "arbitrary" is of no consequence: we designed them to be illustrative of a broad range of possible outcomes.

O'Neill et al. (1) also claim that our assumed future reduction in mortality will have "substantial effects on population growth" compared with one where juvenile and adult mortality trends are decoupled. The authors are incorrect. We reran our Scenario 2a by maintaining the halving of juvenile mortality to 2100, but instead invoking only a one-quarter reduction in mortality of older ages, to emulate a more heavily tapered change in demographic rates that were already low. This approach resulted in a population size in 2100 of 9.79 billion [a difference of 5.4% compared with the outcome of Scenario 2a in the original paper (3)]. Compared with the larger fertility-reduction scenarios (e.g., worldwide one-child policy: Scenario 3), this aspect makes little difference. Similarly, removing the redistribution of fertility to older age classes from Scenario 2a (all other parameters identical) changed the 2100 population size by only 0.1% (10.36 vs. 10.35 billion). The critique that we "unfairly" combined declines in mortality and fertility (2) is also demonstrably false: the mean correlation between total fertility (children/female) and juvenile (<5 y) mortality (per 1,000 live births) from 1970 to 2012 (data available from gapminder.org) for a sample of 24 representative countries (Argentina, Botswana, Brazil, Cameroon, China, Colombia, Ethiopia, Guatemala, India, Japan, Liberia, Malawi, Mexico, Mozambique, Nepal, Nigeria, Pakistan, Philippines, Poland, Russia, United Republic of Tanzania, Thailand, Uganda, Zimbabwe) was 0.86 ± 0.19 (SD; Pearson's correlation coefficient).

Contrary to O'Neill et al.'s (1) claim, we did include a midrange fertility reduction to 2.0 children per female by 2020 (see Discussion in ref. 3), which gave 0.78 billion fewer people globally by 2050 than the business-as-usual scenario. However, such midrange scenarios of 1.5 children per female are practically irrelevant given the original conclusion that even a one-child policy would not, in itself, produce environmentally sustainable outcomes by 2100.

It is worth reiterating that our paper (3) advocates explicitly for a greater global emphasis on fertility reduction via humane family planning, However, our main conclusion—which has not been altered by these critiques—is that over the next century at least, our largest and most immediate gains in sustainability will necessarily come from reductions in per capita consumption, whereas the benefits of fertility reduction will improve humanity's prospects cumulatively over the long term. It is all a question of where society can have the biggest sustainability bang for its social engineering buck in the near term. In this context, although the population-related reductions in greenhouse-gas emissions suggested by O'Neill et al. (1) might be plausible, they will be small relative to the extensive decarbonization that could be achieved through social and technological innovation. If human population size is an elephant in the room, there are even bigger pachyderms roaming through the house.

Our conclusions are therefore robust and remain valid.

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