

The Consequences of Increased Population Growth for Climate Change

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Acknowledgements

The author thanks Mark Weisbrot, Dan Beeton, and Alex Main for helpful comments and Eileen O’Grady for editorial assistance.

Introduction

So long as the world depends on carbon to fuel economic activity, the future of the climate will depend on the scale of that activity. The extent of climate change depends in no small part upon the pace of growth in per-capita output as well as upon population growth.

As such, the harm caused by faster population growth is clear. A larger population requires more farmland to produce food, and increased economic activity means greater carbon emissions and more intense climate change.¹ A recent study estimated that by 2100, slower population growth could reduce carbon emissions by 40 percent, significantly slowing the projected rise in average global temperatures.²

But policymakers in many countries view slow population growth as a source of concern. In Denmark, low birth rates have garnered attention sufficient to spur one company to offer incentives for couples to conceive while on vacation.³ In Iran, Ayatollah Ali Khamenei seeks to reverse the historic fall in that nation's birth rates.⁴ And in Japan, *The Economist* has referred to population declines as a "demographic time bomb."⁵ What is the harm in slower population growth?

In fact, slow population growth need not make public programs unaffordable. In the United States, for example, the difference in per-person income growth between the Social Security Trustees' High Cost (low population) and Low Cost (high population) scenarios is about 6/100ths of 1 percentage point, or less than 5 percent by 2090.⁶ By contrast, the Congressional Budget Office estimates that per-capita income will have grown 235 percent between 2014 and 2089.

Thus, productivity gains by far overwhelm any age effects of slow population growth, and generally only minor changes are required to cover promised pension benefits. Even 75 years from now, the

1 Eduardo Porter, "Reducing Carbon by Curbing Population," *The New York Times*, August 5, 2014, <http://www.nytimes.com/2014/08/06/business/economy/population-curbs-as-a-means-to-cut-carbon-emissions.html?ref=business>.

2 O'Neill, B. C., M. Dalton, R. Fuchs, L. Jiang, S. Pachauri, and K. Zigova. "Global Demographic Trends And Future Carbon Emissions." *Proceedings of the National Academy of Sciences* 107, no. 41 (2010): 17521-7526. Accessed December 9, 2014. <http://www.pnas.org/content/107/41/17521.full>.

3 Heather Saul, "Do it for Denmark: Competition Calls for Danes to Have More Sex to Tackle Declining Birth Rates," *The Independent*, March 28, 2014, <http://www.independent.co.uk/news/world/europe/do-it-for-denmark--competition-calls-for-danes-to-have-more-sex-to-tackle-declining-birth-rates-9218490.html>.

4 "Iran's Leaders are Worried About Their Country's Declining Population," *The Economist*, June 7, 2014, <http://www.economist.com/news/middle-east-and-africa/21603477-irans-leaders-are-worried-about-their-countrys-declining-population-make-more>

5 "The Incredible Shrinking Country," *The Economist*, March 25, 2014, <http://www.economist.com/blogs/banyan/2014/03/japans-demography>

6 We scale the Intermediate projection for GDP by the High and Low projections for population aged 20-64 and divide by the corresponding projections for total population. Thus, the estimated relative per-person income is equal to the ratio of the total dependency ratios (each plus 1.0) for a difference of 4.7 percent by 2090. This difference includes variation in life expectancy as well as fertility. See <http://www.ssa.gov/oact/TR/2014/lr5a2.html>

Social Security program could pay a higher real monthly benefit to retirees with no changes whatsoever. With a small tax increase, the program can pay all promised benefits and leave real wages more than 50 percent higher than today.⁷

To take a more extreme example, the United States spends some twice as much per person on health care and still lags behind in life expectancy when compared to other highly developed countries. If the U.S. spent like its peers, the long-run budget would be in surplus. In the United States, the government's long-term fiscal deficit is driven almost entirely by the high and rising cost of health care spending per person-- not population aging.

In this paper, we step through the construction of relatively simple socioeconomic projections, observing the chain of effects that population growth has upon climate change. We find that our rough estimates agree with the more detailed assessment and produce a rough rule of thumb: An additional 1 percentage point of population growth through the end of the century may coincide with an additional 2 degrees Fahrenheit in average global temperatures.

Population Growth and Climate Change

We employ the Global Change Assessment Model (GCAM) to estimate the effects of population growth on the change in global average temperature by 2100. Roughly speaking, increases in population growth raise growth in Gross Domestic Product (GDP) one-for-one. Depending on the state of energy technology at the time, GDP translates proportionally into releases of carbon dioxide (CO₂). These emissions cumulatively increase the concentration of CO₂ in the atmosphere. Finally, global average temperature increases in proportion to the logarithm of CO₂ concentration. (That is, each *doubling* of CO₂ in the atmosphere increases temperatures by some constant amount.)

Taken together, these assumptions suggest that in any given year—holding constant productivity and technology—global temperature is logarithmically related to population. That is, if population *growth* is constant, then global temperature should in any year be linearly related to growth.

This is truer in the long run and with higher rates of greenhouse gas (GHG) emissions. In the shorter run or with reduced emissions, concentrations are increasingly based on historical emissions unrelated to current socioeconomics.

⁷ Social Security Administration. "B. Economic Assumptions and Methods," *2014 OASDI Trustees Report*, http://www.ssa.gov/oact/tr/2014/V_B_econ.html#292722

Elements other than population do come into play. Faster or slower population growth may change the proportion of the population that is of working age and therefore engaged in production. Cumulative emissions depend on the population path and the distribution among various economies rather than just the current global population. Higher levels of output may raise the price of fossil fuels, inducing production to be less carbon-intensive. Carbon cycles in and out of the atmosphere, and of course CO₂ is not the only relevant gas to consider when projecting climate change.

To handle most of these complications, we turn to an *integrated assessment model* (IAM). There exists a good deal of variation among IAMs, each with strengths and weaknesses, focusing on regional or global economies. One publicly available model, GCAM⁸ (previously MiniCAM), links 14 regional economies through a global energy market. For each region, GCAM takes as exogenous the population, the population's participation rate in the labor force, and the growth in the average productivity of each participant. In this paper, we adopt the productivity assumptions in the Reference scenario provided with the GCAM model. By varying the socioeconomic inputs to GCAM (specifically population and labor force participation) we may predict the impact of population growth on global average temperature.

Socioeconomic Projections

To construct our scenarios, we use population projections from the United Nations Department of Economic and Social Affairs (DESA).⁹ The 2012 World Population Prospects provides eight different projections for population by country, five-year age group, and sex for every five years through 2100.¹⁰ Of the eight projections, we consider three similar variants—the Low, Medium, and High. We also construct a less demographically rigorous variant (Very Low) with very low population growth.¹¹

Each country is assigned to one of the 14 regions as closely as may be determined.¹² For each variant-region-year, we compute the total population and the share of the working-age population

8 University of Maryland. "Global Change Assessment Model (GCAM)," Accessed 9, 2014. http://wiki.umd.edu/gcam/index.php/Main_Page

9 United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Prospects: The 2012 Revision, Volume I: Comprehensive Tables ST/ESA/SER.A/336.

10 United Nations, Department of Economic and Social Affairs, Population Division (2013). World Population Prospects: The 2012 Revision, Extended Dataset, http://esa.un.org/wpp/ASCII-Data/DISK_NAVIGATION_ASCII.htm#DB03_Population_ByAgeSex_Quinquennial2.

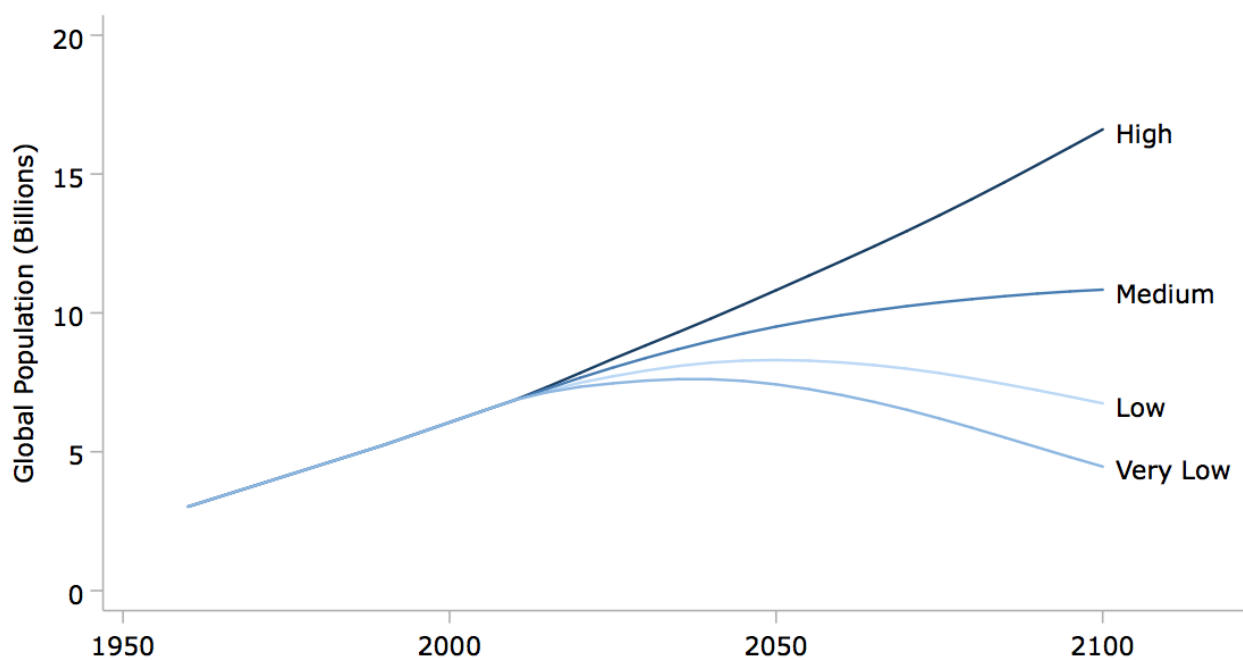
11 For every country, year, age group, and sex, we simply assign a Very Low population such that the Low variant population is the geometric mean of the Very Low and Medium populations. That is, the Very Low equals the square of the Low divided by the Medium.

12 See "GCAM 3.0 Agriculture and Land Use: Data Sources and Methods," U.S. Department of Energy, December 2011, Table A.1 http://www.pnl.gov/main/publications/external/technical_reports/PNNL-21025.pdf. Note that the assignments are largely geographical. The inclusion of Taiwan into the "China" region is not a statement regarding its political status.

(age 20-64). Based on the Reference labor force participation rate (presented as a share of total population) we re-compute the 2005 participation rate as a share of working-age population. We assume that between 2005 and 2050, this share moves linearly to 85 percent and holds thereafter. Finally, we readjust the projected participation rates to be shares of total population and then scale total population so that each region's population matches the Reference scenario in 2005.

Figure 1 shows the resulting global populations for each variant. The populations in 2100 for the primary variants (Low, Medium, High) range between 6.7 and 16.6 billion with an extended (Very Low) projection of 4.5 billion.¹³ Both the Low and Very Low variants show declining populations in the second half of the century.

FIGURE 1
Global Population



Source: DESA and authors' calculations.

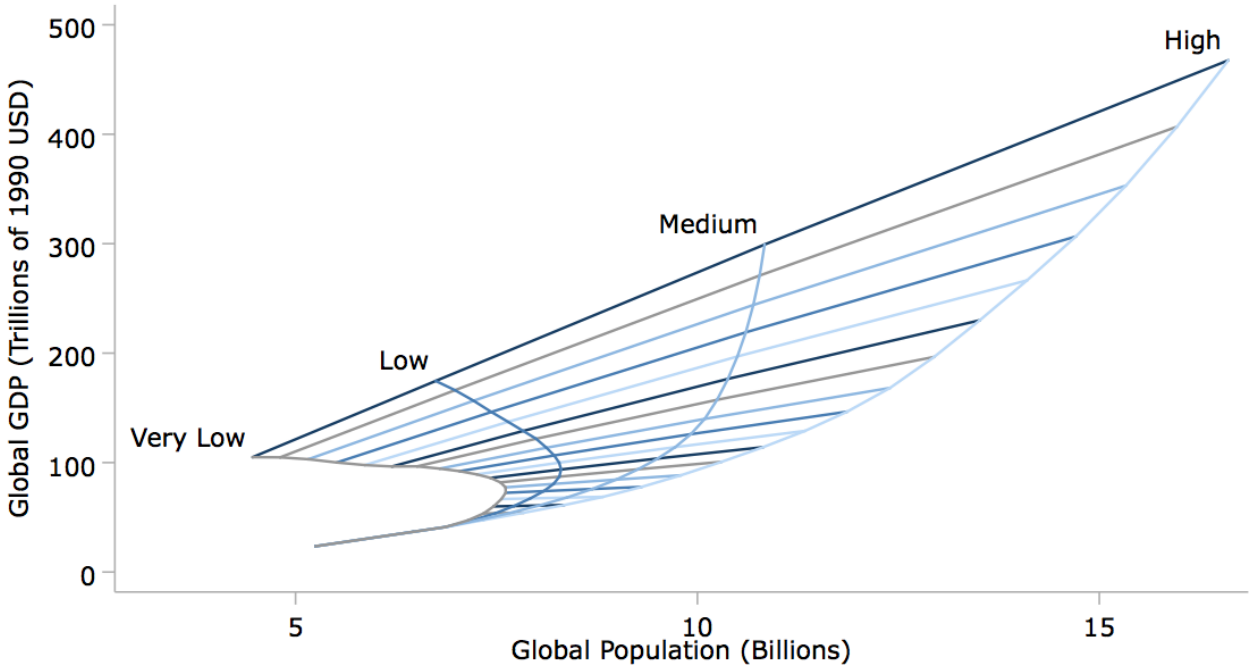
The Reference scenario is successively modified in turn to reflect each variant's estimate of population and labor force participation and the adjusted scenario is input into GCAM.

¹³ Due to the effects of aggregating regions, the total population in the Very Low variant is larger than would be estimated from a direct application of footnote 11.

Model Socioeconomics

By default, CGAM estimates GDP directly from socioeconomic inputs. **Figure 2** shows the evolution of world GDP (in 1990 USD PPP) for the four scenarios. Observations are connected by scenario and by year, with each straight colored line representing a year (in this case, the top line is 2100).

FIGURE 2
World GDP

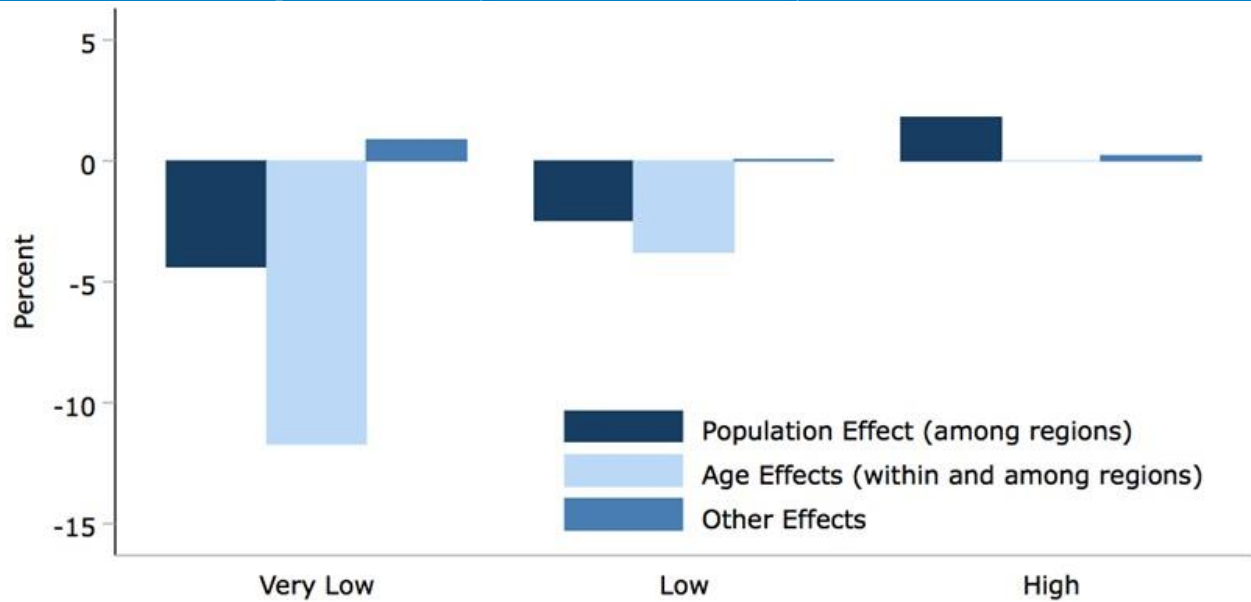


Source: GCAM, DESA, and authors' calculations.

GDP is nearly proportional to population, but per-capita GDP varies by scenario on account of age and aggregation of populations of different productivity as seen in **Figure 3**. For each region, we hold constant productivity across scenarios, so there is no direct effect of population on per-capita GDP.

FIGURE 3

Contributions to Per-Capita GDP in 2100 (relative to Medium scenario)



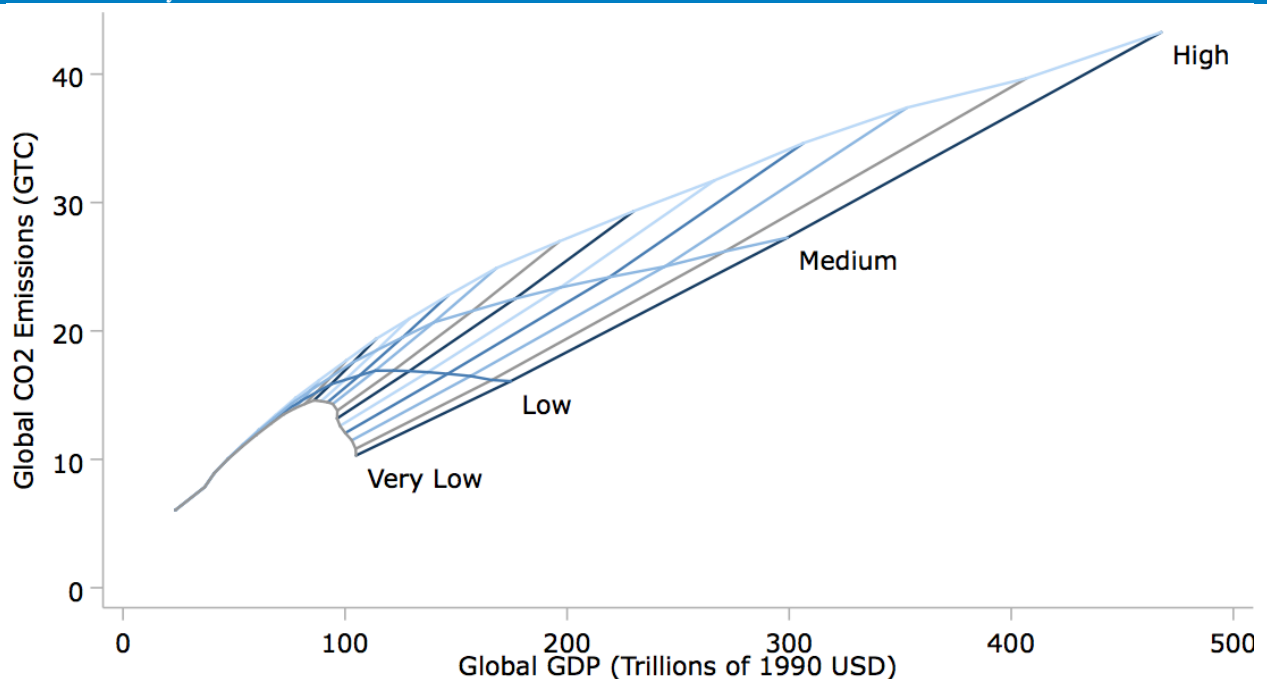
Source: GCAM, DESA, and authors' calculations.

Model Results

Economic output results in increased emissions of CO₂, though the efficiency of carbon consumption improves over time. We see this in the GCAM results of **Figure 4**.

FIGURE 4

CO₂ Efficiency of GDP

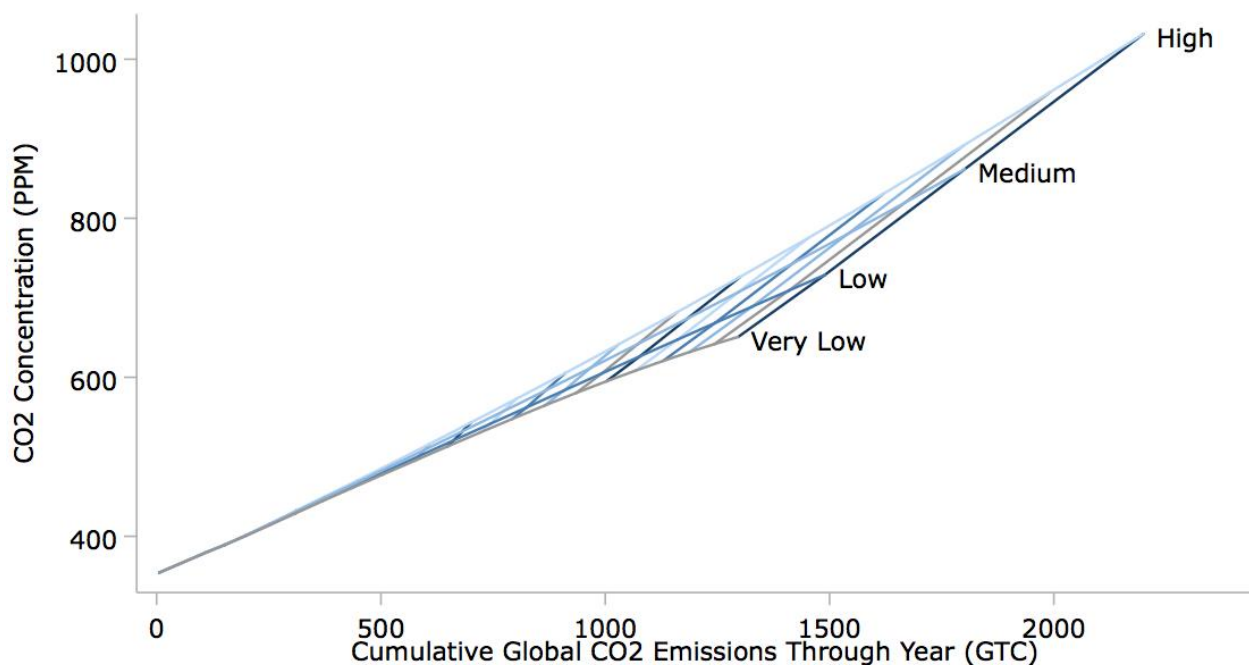


Source: GCAM, DESA, and authors' calculations.

These projections are derived from a relatively high-emissions baseline. By way of comparison, the more detailed estimates¹⁴ show emissions of about 19 gigatons of carbon (GtC) in 2100 for the A2 medium-population scenario and rising to 30 GtC for the high. Nevertheless, from the Medium to High scenario the relative increase in emissions here is comparable—some 59 percent.

Though a small proportion of matter in the atmosphere, once it is introduced CO₂ remains there for a relatively long time. Thus, concentration of CO₂ is closely related to cumulative emissions made over long periods. **Figure 5** shows the relationship between emissions and concentration of CO₂.

FIGURE 5
CO₂ Emissions and Atmospheric Concentration



Source: GCAM, DESA, and authors' calculations.

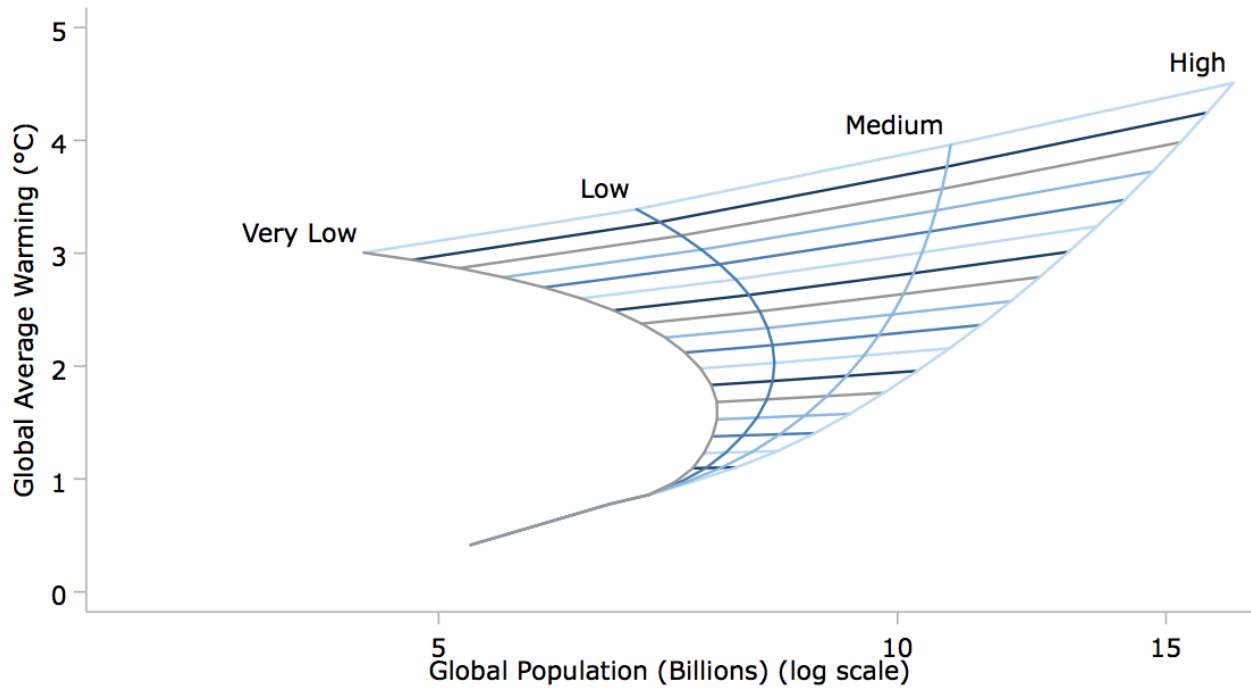
The above relationship is not identical from scenario to scenario, as CO₂ is not the only climate driver varying with socioeconomic alternatives. However, CO₂ concentration clearly provides a large amount of information. Temperature is roughly proportional to logarithm of CO₂ concentration.

Stepping back away from CO₂ as a specific driver of temperature, however, in **Figure 6** we may observe directly the relationship between population and GCAM temperature results based on all modeled forcings.

¹⁴ See: O'Neill, Dalton, Fuchs, Jiang, Pachauri, and Zigova. "Global Demographic Trends and Future Carbon Emissions," Figure 4, <http://www.pnas.org/content/107/41/17521/F4.large.jpg>.

FIGURE 6

Population and Climate Change



Source: GCAM, DESA, and authors' calculations.

GCAM results based on these socioeconomic scenarios show that a 1 percentage point increase in the average annual rate of global population growth between 2005 and 2100 may raise temperatures by an average of 2 degrees Fahrenheit. Over time, the temperature change is greater and becomes increasingly sensitive to population growth.

As noted previously, this result derives from a relatively high emissions baseline. If technology or economics (such as reducing work hours¹⁵) produces a path of lower emissions, then the impact of population growth may be correspondingly lessened. However, there does appear to be an important climate benefit to slower population growth.

Conclusion

We have seen that population growth worldwide will help determine the extent of climate change. While many fear the impact of an aging population, such demographic changes passed quietly in most developed countries and future policy changes may be relatively small.

15 See: David Rosnick, "Reduced Work Hours as a Means of Slowing Climate Change," Center for Economic and Policy Research, February 2013, <http://www.cepr.net/documents/publications/climate-change-workshare-2013-02.pdf>.

On another part of the political spectrum, there is a reluctance to discuss the impact of population growth on climate change for fear of promoting a Malthusian or even racist discourse. However, even if one were to focus on the geographical areas with the fastest-growing projected population – most importantly, Africa – the most important policies that would reduce population growth aim to satisfy the basic unmet needs of individuals and families. Low-income countries have high population growth rates because they are in the process of a “demographic transition” from a state of high birth rates matched by high mortality rates, to a state of lower birth rates and lower mortality rates, and therefore lower population growth. Higher-income countries, and to varying degrees middle-income countries, have made this transition.

There are many positive economic and social policies that can promote this transition to lower birth rates.¹⁶ Among them are: more security in old age, which reduces the need for people to have children for support when they are older, or help with farming; the education of girls and women and increased economic opportunities for them, as well as affordable contraception and reproductive choice; lower infant and child mortality, which reduces the need for families to have more children based on probability of survival; and increased literacy, education levels, and productivity generally. These are some of the most fundamental features of economic development. It is much more prejudicial to the interests of people in developing countries to focus solely on direct reductions of greenhouse gas emissions than it is to recognize the benefits of reducing population growth through economic and social progress.

As for the high-income countries, it is often assumed that since some of them have low or zero population growth, there is not much reduction in population growth that can occur. However, population growth can also be negative, as it is today in Germany and Japan; and it can be further reduced even when it is negative. Any reduction in population growth in high-income countries, even starting from zero or negative rates, will have much more impact on reducing climate change than the same size reduction in low-income countries, because of the much higher per capita consumption and greenhouse gas emissions in the high-income countries.

A worldwide effort at lower population growth will not prevent significant climate change. More comprehensive efforts to prevent carbon emissions in particular will be required and they will be needed soon. However, fears about supporting an aging population do not preclude accelerating--let alone warrant reversing-- the demographic transition to low population growth.

¹⁶ For overviews, see Sachs, *Common Wealth: Economics for a Crowded Planet*, Chapters 7 and 8; and Lam, and David, 2011. "How the World Survived the Population Bomb: Lessons From 50 Years of Extraordinary Demographic History." *Demography* , 48(4): 1231-1262.

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