

Demographics and Productivity: Drivers of Economic Growth

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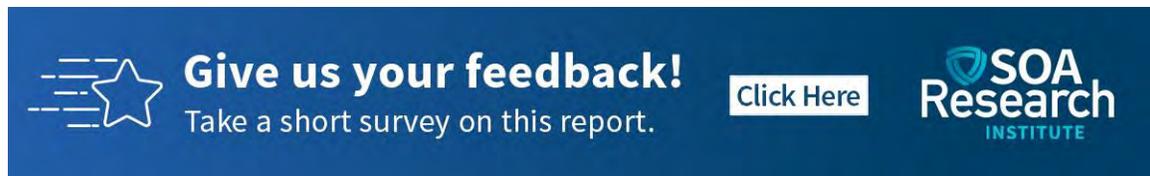


Demographics and Productivity:

Drivers of Economic Growth

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CONTENTS

- Executive Summary 4**
- Section 1: Introduction 5**
- Section 2: Literature Review 9**
 - 2.1 Constraints on animal populations9
 - 2.2 Comments by Franklin and Malthus prior to 1800.....10
 - 2.3 Historical Discrimination10
 - 2.4 Fourth Turning11
 - 2.5 Population aging and implications for asset values.....12
 - 2.6 Limits of Economic Growth.....13
- Section 3: Role of Population and Productivity on Economic Growth 15**
 - 3.1 Economic Growth Broken Down.....16
 - 3.1.1 Productivity18
 - 3.1.2 Population19
- Section 4: Demographic Charts 27**
- Section 5: Other Factors..... 31**
- Section 6: Potential Solutions 32**
- Section 7: Conclusions 34**
 - 7.1 Key takeaways35
- Section 8: Acknowledgments 36**
- About The Society of Actuaries Research Institute 37**

Demographics and Productivity

Drivers of Economic Growth

Executive Summary

Economic growth is how countries measure their financial success, and growth in gross domestic product (GDP) is the metric of choice. The change in GDP can be broken into population change plus productivity change. This paper will describe these component drivers, along with ways to manage them to desired goals.

Leading economies are likely to face obstacles to economic growth in the future. Demographics will be a key challenge as populations age, fertility rates remain below sustainable levels and economic inequality remains high. Some regions, especially sub-Saharan Africa, counter these challenges with strong population growth and a younger population. Threat multipliers that interact with other risks negatively include climate change, regional conflicts, lack of access to fresh water, spillover diseases, chronic medical conditions, technology and cyber risks. The damage they cause goes beyond the direct impacts.

Productivity growth among lower socioeconomic groups offers an opportunity to improve overall economic performance (measured by GDP) while also reducing economic inequality. Historically, GDP has grown steadily upwards until a negative event causes the economy to shrink. These discontinuities in growth are marked by recessions or could be triggered by exogenous events like war, a pandemic or a super volcano eruption that creates food insecurity. Often there are demographic implications, with higher overall mortality and a shift in the mix by sex (war—more males are lost in battles), by age (pandemic—often impacts certain age groups more severely) and by race (ethnic strife leads to losses in certain populations). The costs incurred can be a drag on both growth and demand, leading to lower interest rates as well. Disadvantaged groups are typically the first impacted by an economic downturn.

Resiliency is needed in the financial system to address risks to economic growth and its stability. There is often a difference in opinion in approaches to best achieve resiliency. The approach of government fiscal and monetary policy is directly correlated with the nature of how these issues are addressed. It is common that the objectives of such policies change over time. This can lead to a lack of financial discipline that may directly impact long term economic growth. It is ideal that when setting policy to balance both short term and long-term objectives, rather than focusing solely on one or the other.

The paper proceeds as follows: after an introduction in Section 1, Section 2 provides a literature review and related observations that develop a base for subsequent discussion of the issues. Section 2 includes information ranging from Ben Franklin to historical discrimination to geopolitical cycles and the basics of economic growth.

Section 3 details how GDP growth is driven by its two underlying components: population and productivity changes. Population growth is impacted by fertility rates, increasing old-age dependency ratios and the objectives of immigration/emigration policies. Productivity suffers from inequality and discrimination. Each is challenged by the limited resources of the planet and differences of opinion on the best path forward.

Based on recent trends, it will be a challenge to increase global GDP using domestic population growth alone. The United Nations has created a resource detailing population growth under various scenarios, described in Section 4. Some concerns beyond the scope of this paper are shared in Section 5. Potential solutions are described further in Section 6.

Section 1: Introduction

The Great Depression (1929-1939) and World War II energized the study of macroeconomics as a mathematical tool that could be used to measure and potentially manage the economy for an individual country. While the discussion applies globally, the examples in this paper will focus on the United States and select countries like Nigeria and China.

The last 50 years, and especially since the Asian financial crisis/Russian default in 1998, have seen fiscal and monetary policy often used in concert to achieve financial, and often political, goals. This has left the global economy today in what seems a unique position. Ratios of debt to GDP are historically high in many countries, with central banks battling inflation and emerging markets struggling to pay dollar denominated debt. Stimulus from government spending and central bank measures have started to unwind, and this is expected to stress both asset prices and the Main Street economy.

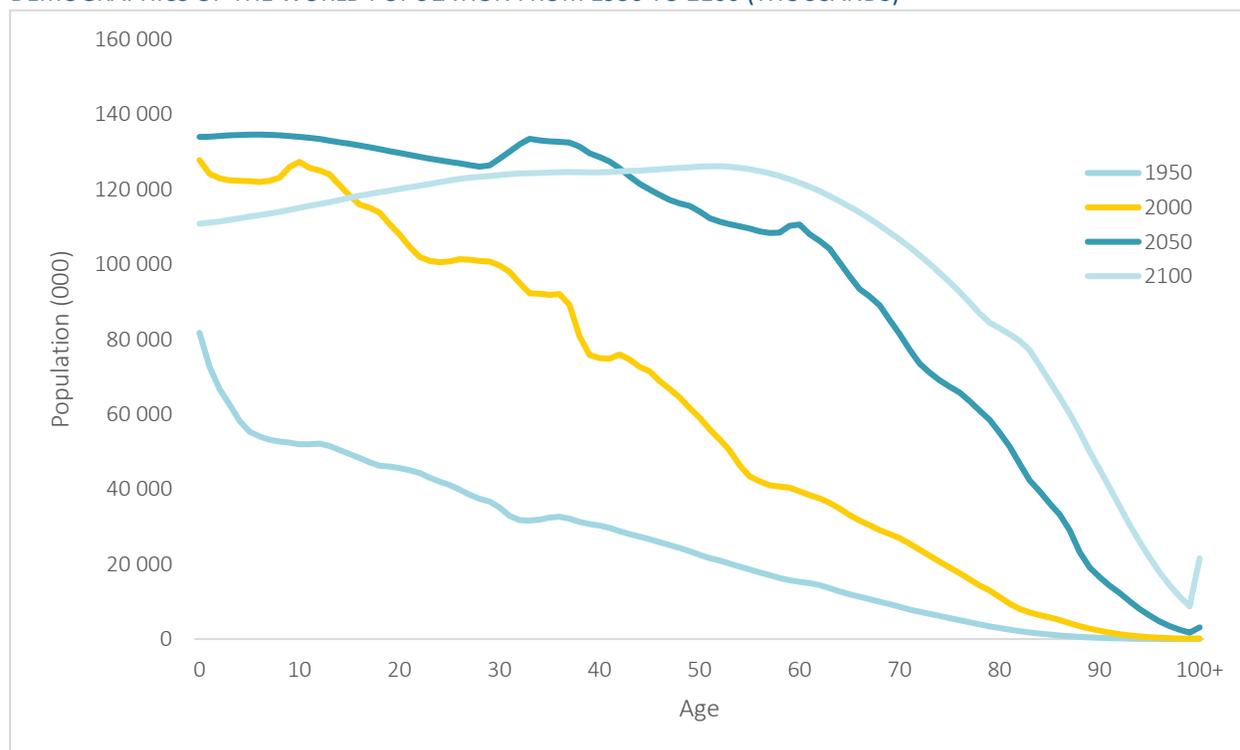
This paper will introduce challenges in the current environment and their potential impact on future GDP. Those highlighted include future demographic expectations that population counts will peak if fertility rates remain below sustainable levels; countries may shift their immigration policies in response to resource changes; and if people continue to live longer there will be old-age (65+) dependency ratio increases.

Complicating the discussion is the U.S. dollar used as reserve currency and the coordination of economic stimulus among the largest world economies. Since many nations use dollar denominated debt, their economic growth is somewhat dependent on U.S. economic policy, especially as it differs from their own. Recent re-thinking of global trade strategies in countries and companies and the pandemic's impacts on supply chains may also impact the future of global growth. Every country has its own story within a story. Some potential solutions related to demographics and productivity will be shared in this paper, but these are not the only ones that may be proposed. A reader may find some solutions more plausible based on their own interpretation of future economic trends. By sharing a variety of scenarios based on future expectations a discussion of their merits can move forward.

Demographic categories include subgroups based on age, gender, race, ethnicity, marital status, income, education and employment. While each interacts with economic growth and will be considered qualitatively, especially as it relates to possible actionable events, generally the focus here will be on age and gender. The subgroups analyzed in various demographic and insurance experience studies typically do not include specific data for some groups that have historically experienced discrimination. This is, in part, because some identifying information is not allowed to be collected by insurers on their policyholders. This has led to sometimes using proxies for this information such as the county of residence to estimate socioeconomic status and measure economic impacts. Given the current lack of robustness of this data, there is clearly an opportunity to further refine such analysis in the future and provide more insightful results.

An analysis from 1950 to 2100 of global demographics is shown in Figure 1. Data by age is compared every 50 years to forecast how world population is expected to grow, and how it is expected to be distributed by age, until 2100. In total, global population, which was at 2.5 billion in 1950, recently passed 8 billion and is forecasted to increase to an estimated 10.3 billion in 2100. As can be seen from the graph, fertility rates eventually fall enough to reduce younger population groups, leaving ever larger older ages with a higher percentage of the total population as the century progresses. Specifically, note that the curve for 2100 is lower at ages 30 and below the 2050 curve. Population growth rates are expected to vary by continent as discussed in Section 4, with the number of people living in sub-Saharan Africa and India growing quickly, North America maintaining growth, and much of the rest of the world (including China) peaking and then regressing.

Figure 1
DEMOGRAPHICS OF THE WORLD POPULATION FROM 1950 TO 2100 (THOUSANDS)¹



Several factors are likely to limit future economic growth in ways that are often not captured by models. A helpful way to think about these factors is through narrative scenarios. Narrative scenarios are formed in a literary way, covering many assumptions and attempting to tell a story about how they interact, as opposed to a model approach. The narrative approach is useful for situations that present complex interactions. In this context, narrative scenarios may be insightful to describe conditions that could lead to low economic growth expectations and convey a qualitative view of the future driven by climate change, energy transitions, inequality, geopolitical tensions and changes in life expectancy. Although it is challenging to model such conditions, new models are being developed that further attempt to integrate these assumption changes, usually for GDP projections. These models are continually improving and increasing in sophistication. Projections often extrapolate from historical results, smoothing results while ignoring tipping points and risk interactions.² This leads to unknown knowns,³ where historical data is not predictive because the future is not expected to mirror the past. Accurate projections require foresight and experience.

Deterministic scenarios can be modeled as a narrative. An example readers may be familiar with is the extension of the Representative Concentration Pathways (RCP) used by the Intergovernmental Panel on Climate Change (IPCC).

¹ Data from UN Population Report Medium Variant Scenario. *United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition.*

² Alberts, Mark and Rudolph, Max. *A Low Growth World: Implications for the Insurance Industry and Pension Plans*. June 2019. Society of Actuaries. <https://www.soa.org/resources/research-reports/2019/low-growth-world/>

³ In 2002 U.S. Defense Secretary Donald Rumsfeld described known knowns and unknown unknowns but he did not discuss the combination unknown knowns. This situation occurs when there is historical data, such as for damage to homes due to wildfire or hurricanes, that is evolving due to an external factor like climate change or pollution. This data will not accurately present future claims and creates a discontinuity with premiums paid, especially over long time horizons. Rudolph, Max J. *Unknown Knowns: Time Horizon*. SOA Climate and Environmental Sustainability 2018 Call for Essays. Pages 7-8. <https://www.soa.org/resources/research-reports/2019/climate-env-sustainability-2018-call-for-essays/>

This is used to present future greenhouse gas (GHG) emissions to the Shared Socioeconomic Pathways (SSP) where a narrative consistent with RCP scenarios is developed. These narrative scenarios are important to understand because of the impact of greenhouse gases on GDP. This is the result of resources needing to be diverted for mitigation and adaptation, including replacement of property and subsidized migration away from areas under threat.

Economic growth is driven by population and productivity. Higher population levels, especially in the primary working ages of 15-64, generate natural GDP growth even when productivity is stagnant. In the developed world, there are challenges to future GDP growth rates from factors including as fertility rates fall below sustainable levels, longevity improvements lead to growth in the retired population and population growth through immigration may, at times, be limited.

The drivers behind population projections vary by country. Table 1 shows some highlights for countries of interest that are experiencing different situations. China's population, among the largest today, is expected to peak soon and then fall through the end of the century. Nigeria represents countries with a rapidly growing population, generally found in sub-Saharan Africa. The United States population is expected to continue to rise at a fairly steady rate. The United Nations projection used in this paper assumes recent immigration policies are maintained or revert to the mean.

Table 1
PROJECTED POPULATIONS IN SPECIFIC COUNTRIES⁴ (MILLIONS)

	2022	2050	2100
Nigeria	218,541	377,460	546,092
United States	338,290	375,392	394,041
China	1,425,887	1,312,636	766,673

There are many factors at play when measuring GDP levels and growth. These were discussed in a 2019 SOA Research Institute publication which the researcher co-authored.⁵ Many potential ideas for further research were suggested in that paper, but one driver seemed a natural extension for further exploration – demographics. As the current project progressed, the researcher and Project Oversight Group considered recently published population projections by the United Nations and International Actuarial Association, it made sense to add productivity as a factor in analyzing GDP growth and focus on productivity and population growth as the two primary components of GDP growth. The United States has been blessed with generally continuous population growth, even in years of pandemics, war and depression. This population growth until now has maintained a relatively young population, with few retirees relative to the work force. This current situation in the U.S. with its relatively younger population against relatively few retirees is not the same in many other countries and will likely be even less so in the future. The U.S. is also likely to face similar demographic shifts that impact the ratio of the younger population to retirees. The complex interaction surrounding population growth, tied to fertility, migration, improved medical treatments

⁴ Data from UN Population Report Medium Variant Scenario. *United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition.*

⁵ Alberts, Mark and Rudolph, Max. *A Low Growth World: Implications for the Insurance Industry and Pension Plans.* June 2019. Society of Actuaries. <https://www.soa.org/resources/research-reports/2019/low-growth-world/>

and even the move to a service economy, is constantly evolving. America is aging and has similarities with other developed nations. Challenges this presents include increasing social safety net costs for the elderly compounded by government debt and increasing climate induced costs. While many of the examples discussed later in this report focus on these challenges in the U.S., this is a global issue as it also impacts other countries.

This paper will not attempt to completely inform solutions for the challenges posed above but seeks to lay out the relevant issues and help inform some potential solutions that can be explored in future research. In thinking about these issues, a number of questions arise. Should GDP growth be the primary metric for an economy? Should population growth be encouraged in all countries through various means? How does climate change, especially temperature change and sea level rise, impact these results? These are questions for others. Here the primary goal is to better understand how GDP growth occurs. How can GDP growth continue after a country's population peaks? That is the question of interest, and information for possible solutions based on optimizing population location and increasing productivity will be considered.

This paper will start out with a literature review of papers to provide context. Some of these papers provide quantitative results for drivers of economic growth. A brief mathematical analysis of GDP growth will follow, along with qualitative ideas about how reduced inequality could lead to higher GDP growth through increases in productivity. Then it will pivot to detail how the demographic traits of various populations are expected to change in this century and how that will inform potential ways of enhancing GDP growth. The paper will conclude by summarizing the findings and suggest ways to anticipate and react to future trends.

Section 2: Literature Review

This section includes observations from related literature on this topic along with general framing questions for consideration throughout the rest of this paper. The impact of demographics on economic growth is multifaceted, intersecting with biological and resource constraints to drive supply and demand interactions. There are many potential outcomes from this multifaceted impact that raise questions. For example, will what is known as the “Malthusian trap”⁶ apply somehow in the future and limit population growth because of agricultural growth limits? Do we now enjoy sustained abundance, or are we borrowing limited resources from future generations? Prior to about 1750 the earth as an ecosystem had been stable since the end of the last Ice Age 10,000 to 12,000 years ago. The Industrial Revolution, which began around 1760, exploited seemingly free resources like clean air and water, long sequestered stores of carbon, unpaid slave labor, expansion to North America from Europe and gold deposits to succeed economically.⁷

Productivity is challenging to measure in aggregate and hard to anticipate in advance. The current technology wave has produced more free time and allowed additional activities, but GDP measures only economic spending. If you get your work done quicker and don’t add a second job, there is no GDP metric identifying you as being more productive. Similarly, a computer model may improve your decision making but does not add to your marginal GDP level.

Results from commonly used metrics to gauge quality of life have mostly been positive in recent times. Life expectancies are longer than ever, although there have been recent declines. Greater literacy, better health and strides toward female empowerment have improved quality of life for many. Sanitation and clean water have reduced child mortality, allowing families to use available resources more efficiently and further leading to productivity gains as a result of higher education levels. Some think these improvements have run their course and health outcomes may prospectively decline due to potential factors such as reverberations of widespread infectious diseases and more toxic air pollution. The uncertainty associated with all these possible outcomes may lead to many financial service providers revisiting the underlying assumptions of the products they offer. Financial products are based on the stability of certain assumptions over their lifetime if the law of large numbers is to hold. Negative exogenous outcomes can put many of these products at significant risk to companies and consumers.

2.1 CONSTRAINTS ON ANIMAL POPULATIONS

Animal populations will grow without bound if there are no constraints placed on them. What are the limiting factors that keep this from happening, working either separately or in combination? Among the resources needed by animals to sustain or grow their populations are access to food and shelter, locations for breeding and lack of predators. For example, as a local population of rabbits expands each of these resource requirements is challenged. More predators arrive to feast on the expanded population and more rabbits per square meter make it harder to find enough food. The ecosystem, in a form of supply and demand, eventually reaches a balance, although some systems have boom-and-bust cycles that take longer to rebalance.⁸ Some events, like wildfires and floods, overwhelm populations with massive die-offs (where a significant portion of a population dies naturally without human activity over a short period of time) and create a clean slate for old and new species alike.

⁶ In a Malthusian trap the population grows faster than the ability to feed itself, providing a limit to population growth.

⁷ These comments are based on an interview with the authors of *How the World Became Rich*, Mark Koyama and Jared Rubin. Matthews, Dylan. *About 200 years ago, the world started getting rich. Why?* June 1, 2022. Vox. https://www.vox.com/future-perfect/2022/6/1/23138463/how-the-world-became-rich-industrial-revolution-koyama-rubin?utm_medium=10today.us.sun.edition.rd.20220605.436.1&utm_source=email&utm_content=article&utm_campaign=10fortoday4.0styling

⁸ National Geographic. Encyclopedic entry. *Limiting Factors*. <https://education.nationalgeographic.org/resource/limiting-factors>

One highly researched interaction in the animal kingdom is between the wolf and moose populations on Isle Royale, an island and U.S. National Park located in Lake Superior. Prey and predator typically grow inversely with each other, changing directions only when the ratio has become extreme and no longer sustainable. The geography makes the ecosystem nearly closed, interrupted only when a wolf crosses the ice, a moose swims to the island, or wolves are added by humans to broaden the gene pool or reset the ratio between them. This predator-prey relationship provides checks on growth of each species and illustrates animal population constraints that humans rarely experience.

2.2 COMMENTS BY FRANKLIN AND MALTHUS PRIOR TO 1800

Ben Franklin is known for many things. His thoughts about population growth have been documented but today are rarely discussed.⁹ In 1751 Franklin penned an essay that noted the number of marriages increased when conditions supported growth and were delayed during trying times, with children adjusting the population to the supportable economic environment.

In 1798 Malthus extended Franklin's ideas, analyzing food production and social safety nets.^{10 11} He assumed that food production could increase linearly while population grew exponentially, arguing that eventually the human population would outpace its ability to feed itself. He also felt that helping the poor made the problem worse as natural cycles of population growth and decline are interrupted.

This was a hopeless and fatalistic prediction, and reviewers for over 200 years have delighted in saying Malthus has been "proven" wrong. Human ingenuity has pivoted to new methods that radically increase food production several times since then, often just as the previous method was becoming ineffective.¹² Fertilizer high in nitrogen has progressed from human and animal waste to seabird and bat guano to being chemically derived, and sex education and family planning techniques have led to population controls.

2.3 HISTORICAL DISCRIMINATION¹³

Mehrsa Baradaran posits that protections under civil rights are tied to economics. An individual can't succeed until they are financially secure. In the United States, financial outcomes often favored white Americans, sometimes intentionally and other times unintentionally. Ignoring this type of bias in developing a financial product or process can potentially exacerbate any disparities. Even something intended to be unbiased, such as allowing a bankruptcy to ignore retirement savings or equity in a home, can create a feedback loop of further disparity among race/ethnicities. For example, Black/African Americans on average have much less in home equity than do white Americans. Rigorous statistical methods using double blind studies are not possible for investigating these issues of disparity. However, on an anecdotal basis, it could be observed that past policies have resulted in socioeconomic discrimination.

⁹ "Observations Concerning the Increase of Mankind, 1751," *Founders Online*, National Archives, <https://founders.archives.gov/documents/Franklin/01-04-02-0080>. [Original source: *The Papers of Benjamin Franklin*, vol. 4, July 1, 1750, through June 30, 1753, ed. Leonard W. Labaree. New Haven: Yale University Press, 1961, pp. 225–234.]

¹⁰ Malthus was also influenced by Adam Smith. Smith's concept of the "invisible hand" driving supply and demand first appeared in Smith's famous work, *The Wealth of Nations* (1776), to describe how free markets can incentivize individuals, acting in their own self-interest, to produce what is societally necessary.

¹¹ Malthus, Robert. *An Essay on the Principle of Population*. *Digireads.com Publishing*. 2013.

https://www.amazon.com/Essay-Principle-Population-Thomas-Malthus-ebook/dp/B00EQVXERG/ref=sr_1_4?keywords=malthus+an+essay+on+the+principle+of+population&qid=1654550740&srprefix=malthus%2Caps%2C104&sr=8-4

¹² DeFries, Ruth. *The Big Ratchet: How Humanity Thrives in the Face of Natural Crisis*. 2014. Basic Books.

¹³ Baradaran, Mehrsa. *The Color of Money*. 2017. The Belknap Press of Harvard University Press. This section is based primarily on information detailed in this book.

Here are some examples from American history:

- Early attempts by philanthropists to establish banks that served Black/African Americans were overwhelmed by financial challenges and pressure to make a profit. These included bank failures such as the Freedman’s Bank in 1874 and Dunbar National Bank in 1938 (despite being backed by John Rockefeller).¹⁴ Regulatory bodies allowed these banks serving Black/African Americans to go under rather than taking measures that could have rescued them.
- Historically, deposits in banks serving Black/African Americans came almost exclusively from Black/African Americans in a local neighborhood or town, but investments were made by these banks in other communities. Black/African American banks had smaller average deposit sizes and more frequent withdrawals, with assets focused on residential real estate. As a result, Black/African Americans using these banks did not benefit economically as would be expected from the money multiplier effect, where a deposit uses credit to effectively create money by a factor greater than one. In other words, monetary growth eluded these Black/African American areas as loans were extended outside the local community; therefore, negating the multiplier effect. This left these banks susceptible to financial downturns. Many Black/African American neighborhoods today are banking deserts, served only by payday loan shops, pawn shops, and other financial institutions that charge predatory rates of interest for their services. A path out of poverty for underserved local communities is inconceivable without local banking options.
- Basic necessities often missing in Black/African American areas include grocery stores, health care facilities, department stores and drug stores. “Everybody owns our own neighborhoods except us,” noted Stokely Carmichael.
- Local communities may look similar in many respects, but property values are generally lower in Black/African American areas. From a property tax perspective, that may seem like a good deal for the Black/African Americans in these areas because of lower taxes. But this limits the tax base, which limits funding for public schools, police and infrastructure. It also makes it harder for Black/African Americans to accumulate wealth because of lower home equity growth.
- Housing discrimination for Black/African Americans has occurred over the years through practices such as redlining, covenants, predatory lending, biased appraisals and unfair actions of real estate agents. This can be exacerbated when zip codes are used as a proxy for health and socioeconomic status.
- Black/African Americans are often the targets of unethical marketing campaigns during economic bubbles like inflated housing prices and when there seem to be no downside money risks. A recent example was the 2008 housing bubble, where there were reverse redlining and “ghetto loans” before it burst.¹⁵
- Since-outlawed practices in the insurance industry also reflected such prejudices. In 1896 a Prudential employee wrote a book stating Black/African Americans were uninsurable because they were destined for extinction. And rather than base poor mortality on socioeconomic circumstances and discrimination, an argument was made that premature death was an inherent physical outcome for Black/African Americans. In response, this encouraged the growth of Black/African American owned insurers, at least for a while.

2.4 FOURTH TURNING

The Strauss–Howe generational theory, formulated by William Strauss and Neil Howe, describes a [generational theory](#) that has occurred in American history and Western history. Generally speaking, every succeeding generation

¹⁴ Ibid, page 79.

¹⁵ Ibid, page 259. A New York Times article June 6, 2009 by Michael Powell, *Bank Accused of Pushing Mortgage Deals on Blacks*. “African-American and Latino borrowers were about 30% more likely to receive the highest cost subprime loans relative to white subprime borrowers with similar risk profiles and that subprime loans in communities of color were more likely to carry prepayment penalties than subprime loans in majority communities.”
<https://www.nytimes.com/2009/06/07/us/07baltimore.html>

is shaped by the events and efforts of the parents and grandparents that preceded them in a unique way, but these generations repeatedly cycle. In their book *The Fourth Turning*,¹⁶ Strauss and Howe see recurring generational behavioral characteristics and patterns every four generations (about 100 years). At any one time four identified generations are present and these groups sequentially rotate so every four generations the same general characteristics are present and the patterns continue. These generations take on specific roles as they graduate to older ages that are consistent across cycles and between generations. The final generation of each cycle in the theory, called the fourth turning, is represented by great upheaval. Recent fourth turnings have included the Revolutionary War, Civil War, World War II and current times. These tumultuous periods have similar experiences to past cycles as those alive during the last period pass on. Many of those who subscribe to this theory worry that the period of upheaval covering the 1930s/1940s will be similarly experienced in some form over the next decade. In this theory, past events are not exactly recreated but similar ones replace them. Recent activities of deglobalization and increasing ethnic strife could be signs of a fourth turning.

The cyclical nature of this generation model contrasts with the current modeling techniques that assume continuous economic growth and changes in population. Recessions, wars and technological advancements are among the reasons that current models fall short. For example, a model may assume 2% GDP growth over the next 80 years but clearly there will be surges and shortfalls along the way. Looking at this qualitatively with a macro view of long-term patterns and scenarios such as in the generational theory described in *The Fourth Turning* can be very helpful, especially during long periods of positive results.

2.5 POPULATION AGING AND IMPLICATIONS FOR ASSET VALUES

The SOA Research Institute has published several papers, often with international co-sponsors, about aging demographics and the impact on economic data. The small number of data points and data limitations make the topic challenging, but one series of papers led by Dr. Doug Andrews found the impact of very old age groups to be deflationary and induce lower bond yields.¹⁷

Written by an international actuarial team, this series of papers developed assumptions for use in subsequent papers. General equilibrium analysis was used to explain co-movement of variables in the entire economy with multiple interacting markets. As would be expected in a complex adaptive system there are no closed form solutions, but stochastic models can be developed for this type of analysis.

The team used an Overlapping Generations Model (OLG), including multiple cohorts with output including GDP, labor supply and savings rate, as a template for demographic changes. In two 2016 papers the team reported that:

- An OLG model incorporates labor/capital, consumption/saving, education, fertility, migration and other variables across cohorts to generate demographic populations at various points in time.
- Older cohorts prefer less risky assets.
- Gender differences in behavior and life expectancy can be modeled.

¹⁶ Strauss, William and Howe, Neil. *The Fourth Turning*. 1997. Broadway Books.

¹⁷ Andrews, Doug et al. *Investigating the Link between Population Aging and Deflation*. February 2016. Society of Actuaries. <https://www.soa.org/resources/research-reports/2016/2016-population-aging-implications-impact> all papers in this section point here.

Combining their earlier work on demographics and asset returns, the team found in their 2018 paper that:

- 1% higher population in working ages increases equity returns 1.5-5% annually and lowers bond yields 1-1.5%.
- 1% higher population over 65 reduced equity returns by 0.5% annually and lowers housing prices 0.5-1.5%.
- 1% higher population aged 40-64 reduces the real long bond yield by 1.29%.

Population structure and asset values were viewed across countries to show:

- A larger old population leads to lower returns for both capital and bonds.

The team sought a connection between population structure and bond yields in a 2020 paper, finding that:

- Moving population groups from young to middle aged reduces bond yields.
- Moving population groups from middle aged to old increases bond yields.
- Not all countries and all time periods move in the same way. In some countries (e.g., Canada) yields move more quickly relative to demographics.
- Given current demographic profiles and projections, the team expects 30-40 bp decreases in bond yields over the next 50 years.

The final paper in the series, published in 2021, summarizes findings about population aging and implications for asset values in the U.S., Canada and the United Kingdom.

- Scenarios by country can help to determine the impact of demographics and help to optimize an asset strategy.

History often repeats in similar ways, so it is worth understanding the past and the importance of preparation and building resilience. This is what the Andrews team has done, quantifying the impact of earlier demographic changes. This, of course, comes with uncertainty as populations have been growing throughout the industrial revolution era and there are few data points where population growth is slowing or negative. The relationship may not be linear either, but the direction should be correct. What is clear from these papers is that older populations are correlated with slower growth and lower interest rates.

2.6 LIMITS OF ECONOMIC GROWTH

This paper is meant in part to extend prior work of the author, working with Mark Alberts, in a 2019 paper about reasons for low economic growth.¹⁸ It identified historical data limitations about model assumption extrapolation that likely overpromise future economic growth. Many builders of economic scenario sets, in fact, expect economic growth as measured by GDP to be lower for most developed countries during the next 50 years. Over longer time horizons GDP growth drives returns as dominant trends overcome short-term volatility. Decreases in relative levels of GDP reduce demand, lowering returns on assets from previously expected levels.

¹⁸ Alberts, Mark and Rudolph, Max. *A Low-Growth World: Implications for the Insurance Industry and Pension Plans*. Society of Actuaries. June 2019. <https://www.soa.org/resources/research-reports/2019/low-growth-world/>

Table 2 below shows the historical per capita GDP growth rate for the U.S., China and the World as compared to projections for the next 50 years using the 20 scenarios described in the 2019 paper.

Table 2
GDP GROWTH

	Annualized per capita GDP Growth Rate		
	U.S.	China	World
Historical 1960-2010	2.1%	6.5%	2.1%
Scenarios (20) 2010-2060			
Mean	1.1%	3.1%	1.6%
Median	1.1%	3.4%	1.6%
Minimum	0.2%	1.5%	0.3%
Maximum	1.7%	4.5%	3.1%

Generally, this is consistent with the work done by the Andrews research team. GDP growth for the largest economies is expected to be about 50% smaller, somewhat offset by larger growth coming from emerging economies.

Future headwinds to growth may include some assumptions that turn out to be too optimistic. Some concerns include:

- Assumed productivity growth driven by technology, education and unlimited resources.
- Assumed unlimited demand.
- Expectations of the future may differ from historical results.
- The global economy is a complex adaptive system and current economic models assume that each person acts rationally. Behavioral finance questions the rationality assumption and incorporating this consideration into economic frameworks could change expected growth outcomes.
- Externalities (indirect impacts of GDP growth) that are ignored. These can be positive or negative. Historical examples include the internet, education and pollution.
- Depletion of resources (e.g., water in aquifers).
- Depreciation may not be static (e.g., accelerates when infrastructure is damaged during hurricanes).
- Stability of assumptions over long time horizons may be impeded by climate change.

Section 3: Role of Population and Productivity on Economic Growth

Historically, gross domestic product has been the metric used to mark successful economic growth. It was developed first as gross national product (GNP) during the depression of the 1930s and formalized after the Bretton Woods Conference in 1944. GDP measures goods and services produced in a country, while GNP measures the goods and services produced by a country's residents anywhere in the world.¹⁹ Other metrics often referenced include gross national income (GNI) and gross domestic output (GDO), an average of GDP and GDI. As can be seen from Figure 2 these metrics will occasionally diverge from each other.²⁰

Figure 2
METRICS USED TO MEASURE OUTPUT IN THE UNITED STATES



U.S. Bureau of Economic Analysis, Gross Domestic Income [GDI], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/GDI>, October 10, 2023.

Concerns with the strictly quantitative measure of GDP for use in setting goals due to inadequate inclusion of externalities like pollution and work/life balance has led some to rely on the Happiness Index.²¹ While it includes GDP per capita, the Happiness Index also includes measures (often surveys) about social support, life expectancy, freedom, generosity and corruption.

The Gini coefficient is a metric used to quantify inequality, often within a country. A ratio of 1 (or 100%) means that all the income or wealth is in the hands of one person and a ratio near zero means there is great dispersion of wealth. Like any metric, seeing the distribution of results across countries and across time is helpful. There are a few variations of the metric and demographics play a role in results. For example, an aging population will have more concentrated wealth even if income is generally more broadly distributed.

GDP is a well-known and widely used metric for growth but has severe shortcomings relating to sustainability and climate change. Broad welfare metrics are increasingly emerging (e.g., the United Nations Human Development Index and the European Union Beyond GDP initiative) and look at societal health measures such as education, women's rights, and the quality of air and water. GDP may be increasing while air quality decreases due to the very industrial activity driving GDP growth. A shortcoming specifically relating to physical climate-related risk is that the

¹⁹ Ramey, Kelly. *The Changeover from GNP to GDP*. Bureau of Economic Analysis (U.S. Department of Commerce). March 2021.

<https://apps.bea.gov/scb/2021/03-march/0321-reprint-gnp.htm>

²⁰ FRED Economic Data, managed by the St. Louis Federal Reserve Bank, is a user-friendly tool. <https://fred.stlouisfed.org/>

²¹ Helliwell, J., et al. *World Happiness Report*. 2022. <https://worldhappiness.report/>

damages to assets due to weather related phenomena are not included in the metric, while investments to rebuild are.²²

Balancing these types of issues is important, and could be included in future research, but this report will retain GDP as its metric of choice. There are several ways to think about GDP, listed below, but our focus on demographics and productivity suggests a look at the first formula listed.

GDP = population x productivity

GDP = money supply (M) x velocity of money (V)

GDP = prices (P) x output (Y)

GDP = consumption (C) + investment (I) + government spending (G) + net exports (NX)

GDP = total national income + sales taxes + depreciation + net foreign factor income

GDP = sum of all value-added to products during the production of a process

3.1 ECONOMIC GROWTH BROKEN DOWN

The drivers of economic growth evolve constantly. Economic growth was small but stable prior to the industrial revolution at 0.2% per capita or less per year.^{23 24} It grew on a nominal basis during the colonial period as gold mining in newly colonized areas expanded currencies, natural resource exploitation (especially of fossil fuels) took advantage of negative externalities (e.g., pollution) and areas newly discovered by Europeans became opportunities for development.

GDP is typically measured in nominal terms. This can be misleading when inflationary increases mask poor economic conditions. But it also means that disinflationary factors like debt, demographics and disruptive technologies can reduce GDP even when the economy is healthy. Stagflation presents a poor economic environment since GDP is falling and inflation rates are high. Backing out inflation and looking at real GDP growth can be useful, providing nuanced information to aid analysis.

GDP is the multiplicative product of population and productivity. GDP and population can be measured directly. Productivity in aggregate is solved for in this formula. Mathematically, the change in GDP is approximated by the sum of the percentage changes in each of the two factors when the changes are relatively small.²⁵ There are limited ways to increase economic growth. Either population grows or you can increase productivity, and if one of these is decreasing it produces a headwind to economic growth.

Productivity is very hard to measure directly. Computers make us more productive, most would agree, but the price keeps coming down and GDP is measured using sales. The productivity calculation that counts only paid hours incentivizes workers who are salaried to stop after a normal workday. Some will do the least amount necessary to

²² Climate Risk Task Force. *Application of Climate-Related Risk Scenarios to Asset Portfolios*. International Actuarial Association (IAA). April 2022.

https://www.actuaries.org/iaa/IAA/Publications/Papers/Climate_Issues/IAA/Publications/Climate_Issues.aspx

²³ Gordon, Robert. *The Rise and Fall of American Growth*. Princeton University Press. 2017. Gordon notes that Angus Maddison calculated .06% per year from 1 AD to 1820. GDP has been calculated formally for less than a century.

²⁴ Gordon, Robert. *Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds*. NBER Working paper 18315. August 2012.

<https://www.nber.org/papers/w18315> On page 6 Gordon reports that GDP per capita in the UK 1300-1700 was 0.2%.

²⁵ $\Delta GDP(\%) = \Delta Population(\%) + \Delta Productivity(\%) + \Delta Population(\%) \times \Delta Productivity(\%)$ The final component is typically immaterial so is often left off the general formula.

collect their pay and not be fired, an action called quiet quitting. A culture that unintentionally encourages quiet quitting will drive away those who are creative or could get a day's work done in a fraction of the time.

Is GDP the right metric? Should the focus change to per capita GDP or productivity as population levels peak? As previously stated, productivity can be hard to measure, while economists and demographers have good data on population and future projection scenarios. This means understanding GDP growth becomes more complicated.

Population growth accelerated during the industrial revolution when manufacturing activity was organized around gathering places like cities. Initially city sizes were naturally capped since many people living in close proximity accelerated the spread of disease. Once sanitation improved, city sizes became less naturally limited. Mortality rates fell as a result and a demographic transition occurred as more children survived to adulthood. After a generation of explosive population growth, family culture changed resulting in fewer kids and a greater focus on education.²⁶

Potential future discontinuities make it hard to project populations going forward. Events like infectious diseases and wars periodically cause a spike in mortality, but at uncertain times and places. The recent COVID-19 pandemic delayed diagnosis of diseases like diabetes and cancer. The ramifications from vaccine avoidance could lead to future disruptions from diseases including new coronaviruses, influenza, polio and smallpox. All the news is not bad. Positive discontinuities are possibly already underway where treatments for malaria have reduced mortality, especially among children in Africa.

Today's challenges include climate risks, war, energy costs, high debt, low interest rates, inflation, food insecurity, pandemics and deglobalization. High levels of government debt make it challenging for solutions to avoid runaway inflation. The process of globalization over the last few decades has been viewed by many as leaving all parties economically better off and reducing international tensions. On the other hand, recent trends of what is known as "nearshoring" have been pointed out by many to have several advantages. However, many also believe these trends could lead to a lower level of overall wealth and cause a reduction in international cooperation. To address challenges felt during the COVID-19 pandemic, supply chains and domestic manufacturing are being rebuilt to avoid a repeat of the issues these disruptions caused. Doing so in ways that lower inequality is an intended part of the Biden administrations game plan.²⁷

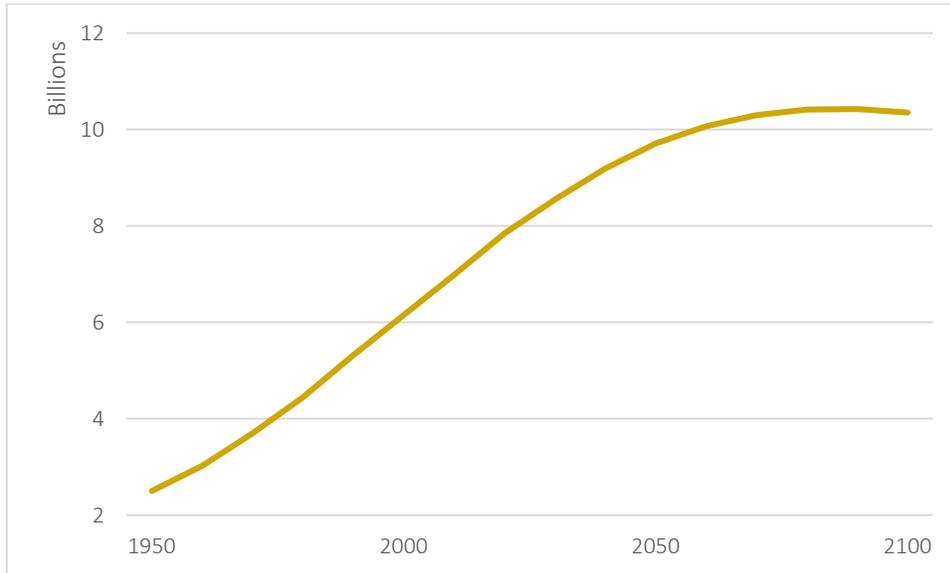
As another example of addressing challenges to productivity and growth, MacKenzie Scott, the ex-wife of Amazon founder Jeff Bezos, has implemented a plan that provides funding to charities with no reporting expectations. Non-profits can spend the money in ways that make sense to them, building buy-in to the plan. With lower overhead it is hoped that resources are used more efficiently.

According to demographers at the United Nations, as shown in Figure 3, peak population levels will be reached and begin to fall before 2100. When population growth is negative, the GDP metric (along with GNP, GDI, GDO) will have a strong tendency to shrink.

²⁶ *How hand-washing explains economic expansion*. The Economist. August 1, 2020. Page 71. <https://www.economist.com/books-and-arts/2020/08/01/how-hand-washing-explains-economic-expansion>

²⁷ In the U.S., President Biden signed Executive Order 14008 early in his tenure. It sets a goal that 40% of the overall benefits of certain Federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution. <https://www.whitehouse.gov/environmentaljustice/justice40/>

Figure 3
GLOBAL POPULATION GROWTH



United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition.

The GDP metric makes sense as a measure of success when populations are rising but may not work as well at peak or falling levels. GDP per capita may make more sense in that it reflects an average result per person or per person of working age. As can be seen in Figure 4, GDP per capita has increased steadily, but not monotonically, since first measured officially in 1947. Drops are typically aligned with recessions.

Figure 4
U.S. GDP PER CAPITA



U.S. Bureau of Economic Analysis, Real gross domestic product per capita [A939RX0Q048SBEA], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/A939RX0Q048SBEA>, October 10, 2023.

3.1.1 PRODUCTIVITY

Productivity is often measured as GDP per hour worked, shown in Figure 5. The trend is comparable to GDP per capita. Other metrics, where the divisor is total population or working aged population, are also used. Aggregate productivity is difficult to calculate, but certain industries can be measured. Additionally, proxies can be developed to provide reasonableness checks.

Figure 5
U.S. PRODUCTIVITY PER HOUR



U.S. Bureau of Labor Statistics, Nonfarm Business Sector: Labor Productivity (Output per Hour) for All Workers [OPHNFB], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/OPHNFB>, October 10, 2023.

For this paper, productivity will be defined as GDP per person in the work force, and the population metric will focus on those in the work force. The paper will also discuss implications of relative size of the work force to total population and relative size of the retired population. Additional thoughts will include ways to increase hours worked for underemployed workers and disadvantaged communities.

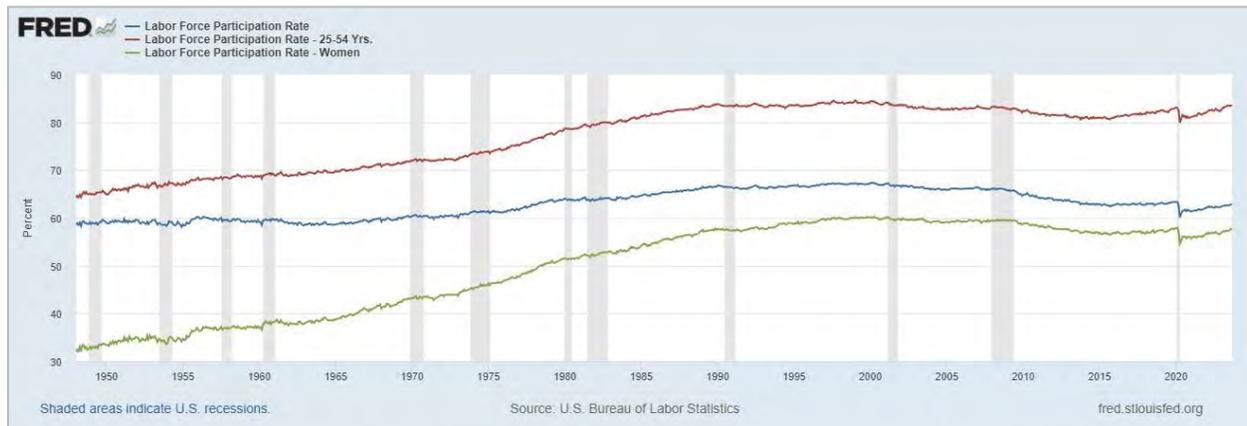
3.1.2 POPULATION

Population can be dissected in many ways depending on the assumed drivers of GDP. A broad view could look at aggregate population, including all ages, or just a segment of that group. When projecting population it is important to utilize age cohorts. What level of detail is needed? Should each age be modeled, or use groupings of 5 or 10 years? Do males and females need to be projected separately? How about the elderly and the young, and how do you define those groups? The U.S. government has defined the answers to many of these questions and this paper will utilize those definitions. Most importantly, they have defined the work force as ages 15-64, with some metrics focused on the key earning years of ages 25-54. Note that when we return to this topic and look at the UN Projections that these definitions are slightly different (but the interpretation of the data trends is unchanged).

Labor Force Participation Rate

Figure 6 combines several labor force participation rates of note, showing how they have evolved since 1947. Movement in the participation rate can cause unexpected results as workers give up and stop looking for work, reducing the unemployment rate. Not surprisingly, the participation rate is highest for those in the key 25-54 age group where earnings peak, but it is below 85% in all years. There are numerous reasons for this to be less than 100% including disability, home makers, students, early retirees and others who neither need nor desire to work. A natural rate of unemployment (NRU) is designed to capture those seeking work as a percentage of those wanting to work. The NRU is a theoretical estimate that helped develop many key economic formulas. Of late many basic economic relationships have evolved in ways that are different from when they were initially derived. This could be temporary due to stimulus programs, temporary reevaluation of life goals or due to a permanent shift. Periodic review of these formulas from first principles is important, as rules of thumb are not appropriate under all conditions. The overall labor force participation rate using the 25-54 age range peaked during the dot.com boom of the late 1990s at just below 70% and is, as of this writing, slightly under 63%. The gap in the rate for women has narrowed due to increased levels of education and increased family planning options.

Figure 6
U.S. LABOR FORCE PARTICIPATION RATES



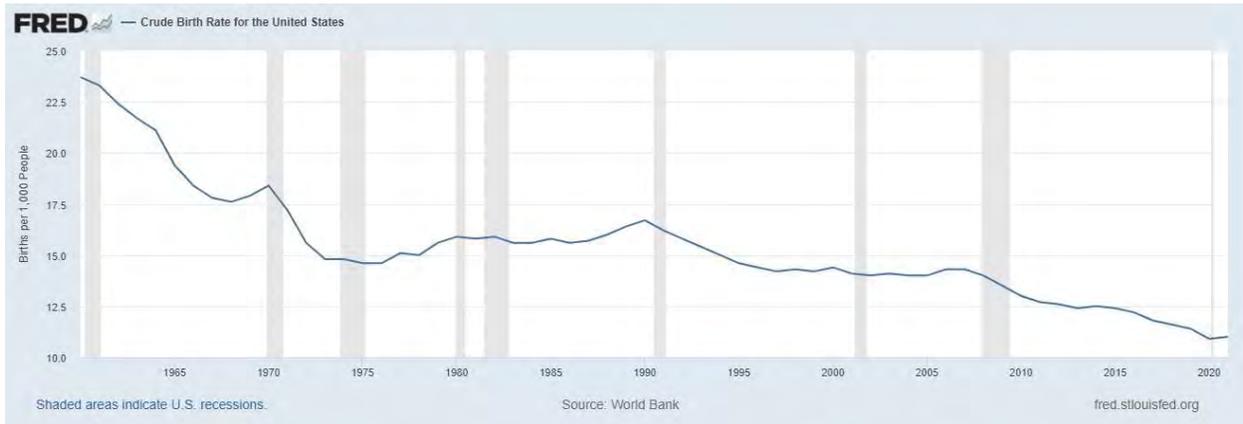
U.S. Bureau of Labor Statistics, Labor Force Participation Rate [CIVPART], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/CIVPART>, October 10, 2023.

Birth Rates

There are many factors leading to a slowing population growth in the United States. The birth rate per thousand people, shown in Figure 7 for the United States, is roughly half what it was 60 years ago. The economic case presented by Franklin in Section 2.2 provided incentives that raised the birth rate in good times and lowered it when economic conditions were unfavorable. The reasons for the decline are not clear. While birth control methods have afforded more choice, other suggested factors include reductions in childhood mortality through vaccines and health practices, later ages for marriage and first child by choice, and lower sperm counts due to factors potentially linked to pollution, chemicals (including PFAS), diet, low physical activity, higher drug use, higher stress and less sleep.²⁸

²⁸ Sullivan, Will. *Human Sperm Counts Declining Worldwide, Study Finds*. November 22, 2022. Smithsonian Magazine. <https://www.smithsonianmag.com/smart-news/human-sperm-counts-declining-worldwide-study-finds-180981138/#:~:text=Other%20environmental%20factors%2C%20like%20exposure,contribute%20to%20lower%20sperm%20counts.>

Figure 7
U.S. BIRTHS PER THOUSAND PEOPLE

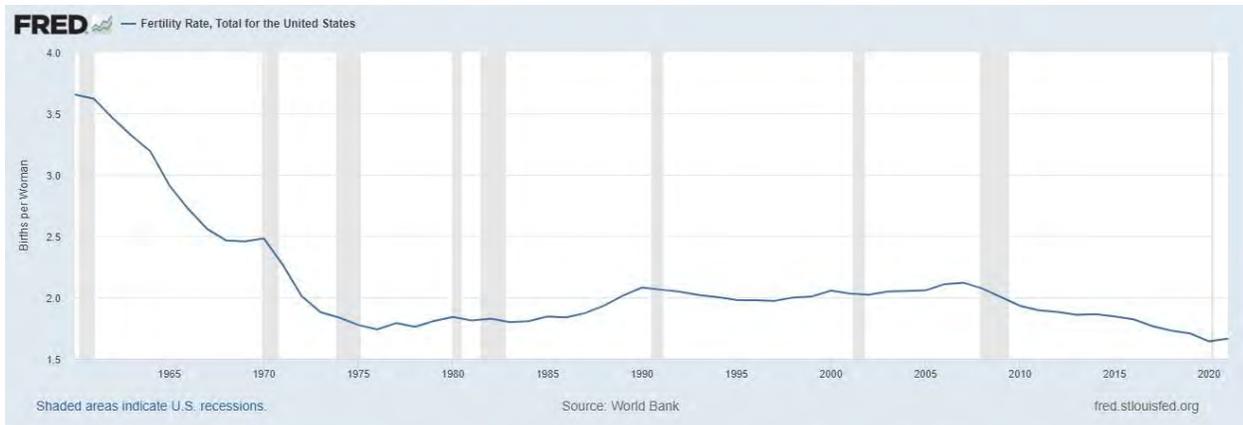


World Bank, Crude Birth Rate for the United States [SPDYNCBRTINUSA], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/SPDYNCBRTINUSA>, October 10, 2023.

Fertility Rates

Per the OECD²⁹, to support a sustainable population the number of births per woman over her lifetime (fertility rate) must be at least 2.1. The most recent rate, recorded in 2021, from one study in the U.S. is 1.66 (1.64 in 2020) and has been below the sustainable rate for over ten years (see Figure 8). Other developed countries also fall short of sustainable rates, with some below 1.

Figure 8
U.S. BIRTHS PER WOMAN



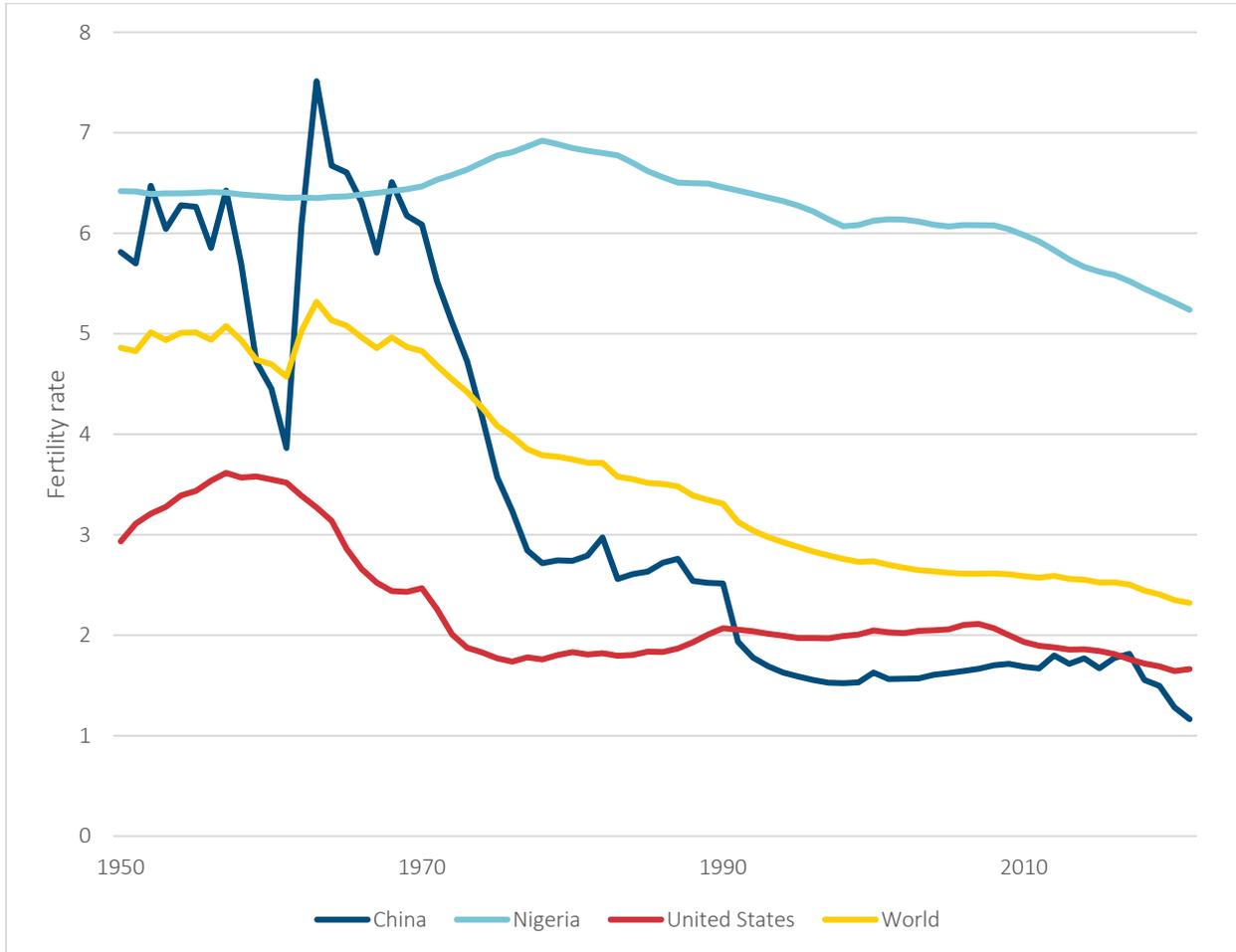
World Bank, Fertility Rate, Total for the United States [SPDYNTFRTINUSA], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/SPDYNTFRTINUSA>, October 10, 2023.

This decrease is not unique to the United States. Even many emerging nations have falling fertility rates, although from higher levels, as shown in Figure 9. For countries with high rates, a practice known to reduce fertility rates and

²⁹ Organization for Economic Cooperation and Development. <https://data.oecd.org/pop/fertility-rates.htm#:~:text=Assuming%20no%20net%20migration%20and,of%20economic%20and%20social%20developments.>

improve economic metrics is to invest in the education of females. Historically this has increased the standard of living and GDP per capita.³⁰

Figure 9
GLOBAL FERTILITY RATES (BIRTHS PER WOMAN) IN SELECTED COUNTRIES SINCE 1950



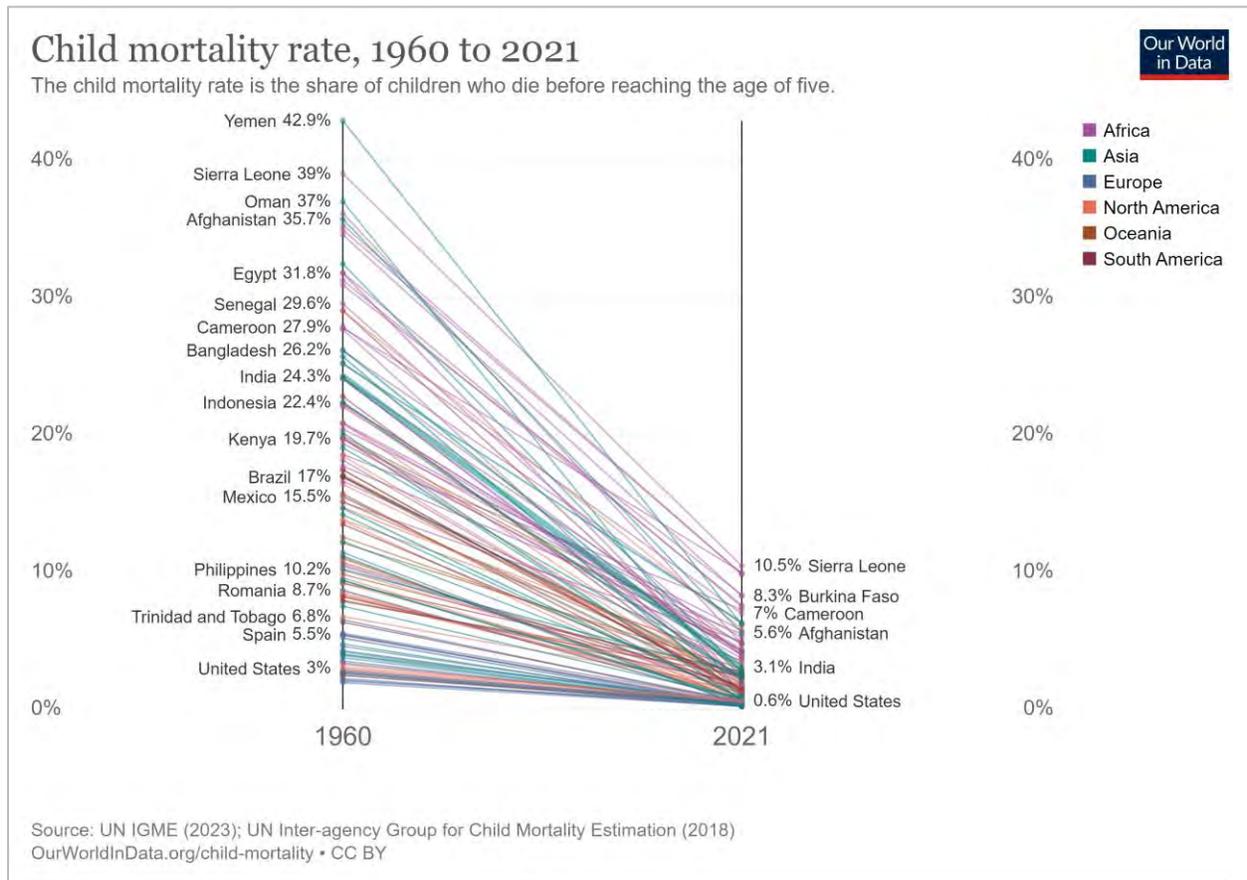
United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Data Sources. (UN DESA/POP/2022/DC/NO. 9).

Offsetting (and consistent with) the lower fertility rate is reduced mortality for the young. Child (below age 5) and infant (under age one) mortality has fallen³¹ from 40% around the world just 200 years ago due to improvements in sanitation, medical care, nutrition, and the treatment of malaria and other infectious diseases. Figure 10 shows this drop over the last 60 years. This improvement is found in countries in all regions and all levels of development.

³⁰ Lagarde, C. and Ostry, Jonathan D. *Economic Gains from Gender Inclusion: Even Greater than You Thought*. International Monetary Fund. November 28, 2018. <https://www.imf.org/en/Blogs/Articles/2018/11/28/blog-economic-gains-from-gender-inclusion-even-greater-than-you-thought>

³¹ <https://ourworldindata.org/child-mortality#child-mortality-achieving-the-global-goal-for-2030-would-be-a-huge-achievement-but-we-are-currently-far-away>

Figure 10
CHILD MORTALITY RATE



Longevity

The COVID-19 pandemic and opioid crisis have recently reduced longevity. Prior to this, populations globally were living longer due to improved medical knowledge and treatments, reduced poverty at the older ages due to social safety nets like Social Security and Medicaid in the U.S., and reduced childhood mortality due to disease (e.g., sanitation and immunization).

Working age as percentage of total population

When it comes to economic output all ages are not equal. The working age population, 15-64, does the heavy lifting in the workforce. Youth, under age 15, and elderly (over 64) are called dependents in this context although many boomers have continued to work beyond age 64 and some youth work prior to 15.³² The pandemic caused a surge in early retirements, but as seen in Figure 11 the old age dependency ratio had been in an upward trend since before the Great Recession. This has large demographic impacts as dependents require resources and, as a result, are a drag on growth.

³² Beilfuss, Lisa. *The Labor Shortage Hits Home*. August 2, 2021. Barron's. <https://www.barrons.com/articles/labor-shortage-worse-than-it-looks-51627664401>

Figure 11
OLD AGE DEPENDENCY RATIO



World Bank, Age Dependency Ratio: Older Dependents to Working-Age Population for the United States [SPPODPNDOLUSA], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/SPPODPNDOLUSA>, October 10, 2023.

Immigration

Immigrants have a broad range of skill sets, from newborns with no current skills to low skilled workers to Ph.D.'s and retirees. They may come to a country to join family, study, find work, escape war or poverty, or as climate refugees. Migration is an important component in determining economic growth and in a declining population is further highlighted. Countries may consider analyzing their demographic situation from a data-driven perspective to determine the optimal role for migration, rather than relying on emotions. Aging populations that limit immigration may find themselves unable to fund desired projects or social programs and may struggle to find service workers. The dependency ratio can be a key analytical metric when determining immigration policy. Strategically considering the impact of immigration may help to further goals such as maintaining strong safety nets and a sustainable age distribution.

Population growth

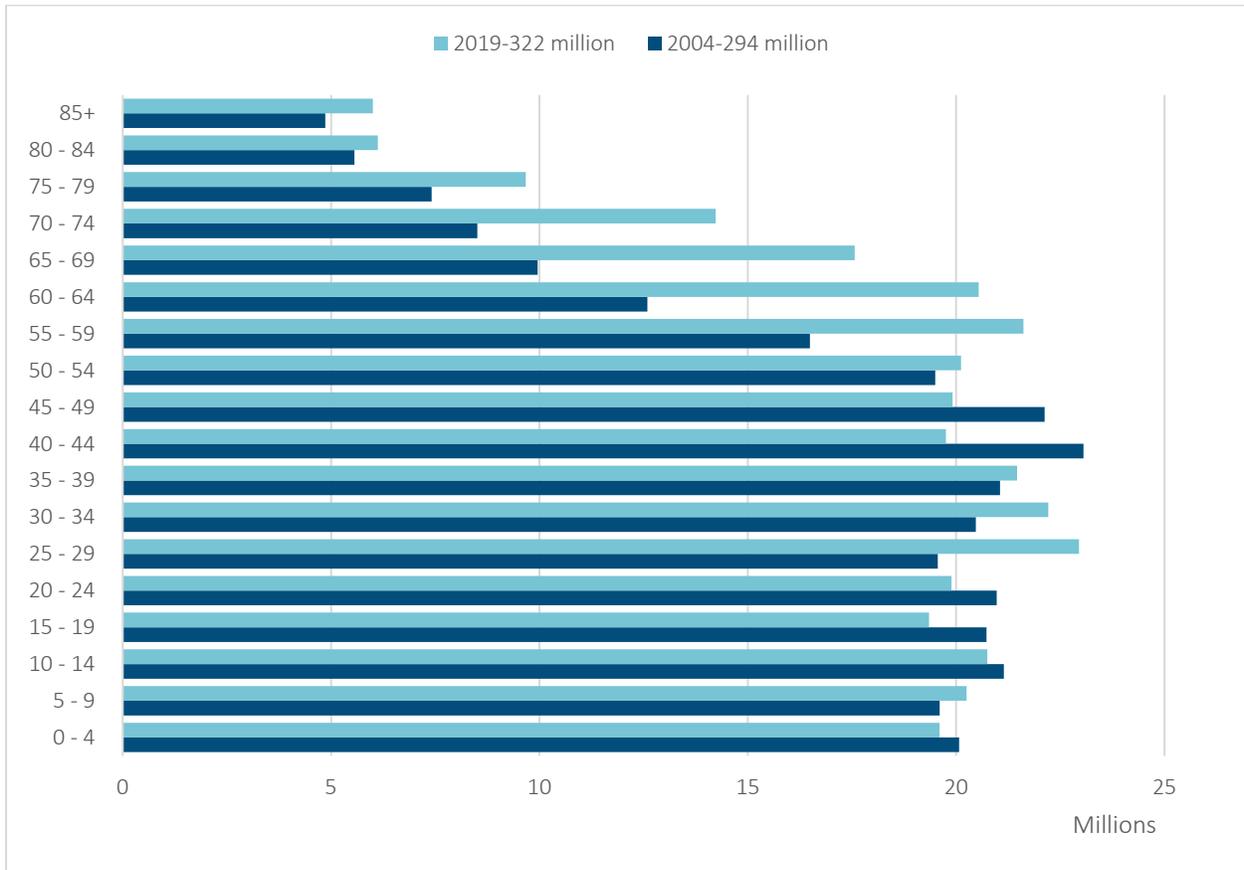
In the U.S., low fertility rates have driven new births down, but total population continues to grow due to immigration and increasing longevity. The dependency ratio is projected to increase leading up to 2100. That can impact the social safety net in many ways and may end up creating a positive feedback loop as elderly voters repeatedly vote for benefits to continue. Many benefits are tied to inflation rates through a cost-of-living allowance (COLA). This may drive a wider range of potential stress scenarios today, e.g., could higher inflation expectations create a positive feedback loop, or could deflation be driven by a high dependency ratio?

The Society of Actuaries published a report in 2007 by Jim Toole that developed pandemic scenarios. These scenarios were updated early in the COVID-19 pandemic, building sensitivities around impacted ages and population growth.³³ A useful benefit from this update is that population data, both historical and projected, can reveal trends that may not be obvious otherwise. For this update, populations were compared to use age-standardized analysis on a current demographic data set, in this case updating from 2004 to 2019. Figure 12 shows the results and that the population had both grown larger by about 10% and older, especially for ages 55 and above. A key result of the analysis is that a modeled pandemic that primarily impacted the elderly, as COVID-19 did initially, had many more

³³ Toole, Jim. *Potential Impact of Pandemic Influenza on the U.S. Life Insurance Industry*. May 2007. Society of Actuaries. <https://www.soa.org/resources/research-reports/2007/research-impact-pan-influ-life-ins/>

deaths than would have been seen in 2004.³⁴ The impact to mortality of this older age category from COVID-19 was material and shows why it is important to periodically review assumptions and rules of thumb to make sure they remain appropriate.

Figure 12
U.S. POPULATION CHANGES FROM 2004 TO 2019 BY AGE



The change in dependency ratio is also revealing, as can be inferred from the Census Bureau population data changes shown in Table 3. While the working age population (shown here using census data and ages 15-64) grew by nearly 6% and the young (ages 0-14) decreased slightly, growth in the elderly population above age 64 had grown by nearly 50%. This resulted in an increase in the dependency ratio from 0.494 to 0.550 and foreshadows further increases as the more populous baby boomer generation continues to progress through the older age group.

³⁴ Rudolph, Max. *Life Pandemic Model Updates to U.S. Life Insurance Industry Moderate Scenario*. Society of Actuaries. January 2021. <https://www.soa.org/resources/research-reports/2021/life-pandemic-model/>

Table 3
U.S. POPULATION BY AGE GROUPS ³⁵

Age group	Population 2000	Population 2019 projected	Percent Increase
Ages 15-64	196,539,423	207,795,638	5.7%
Ages 0-14	60,821,996	60,597,800	-.4%
Ages above 64	36,293,985	53,588,424	47.7%
Total	293,655,404	321,981,862	9.6%

Other trends

Additional trends were already appearing prior to the COVID-19 pandemic. The rate of mortality improvement due to reduced smoking had been slowing for many years. At the same time, unhealthy diet habits created leading indicators suggesting that mortality improvement could reverse to mortality deterioration in the future as related health conditions like obesity and diabetes become more prevalent. Recently, so-called deaths of despair have created new trends. Drug overdoses, mainly from opioids, along with suicides and alcoholism have increased mortality, especially at ages 15-44 in the white population.³⁶ Climate risk is likely to provide another headwind to mortality improvement in as yet unknown ways, both directly and indirectly. As the COVID-19 pandemic further recedes, these trends will need to be monitored as lockdowns resulted in more home cooking, which is presumably healthier, but it led to a generally more sedentary lifestyle during that time and took a toll on mental health for many. Extreme young and old likely were impacted socially during the pandemic and this could be an important trend to monitor and study.

³⁵ www2.census.gov/programs-surveys/popest/tables/2010-2018/national/totals/na-est2018-01.xlsx

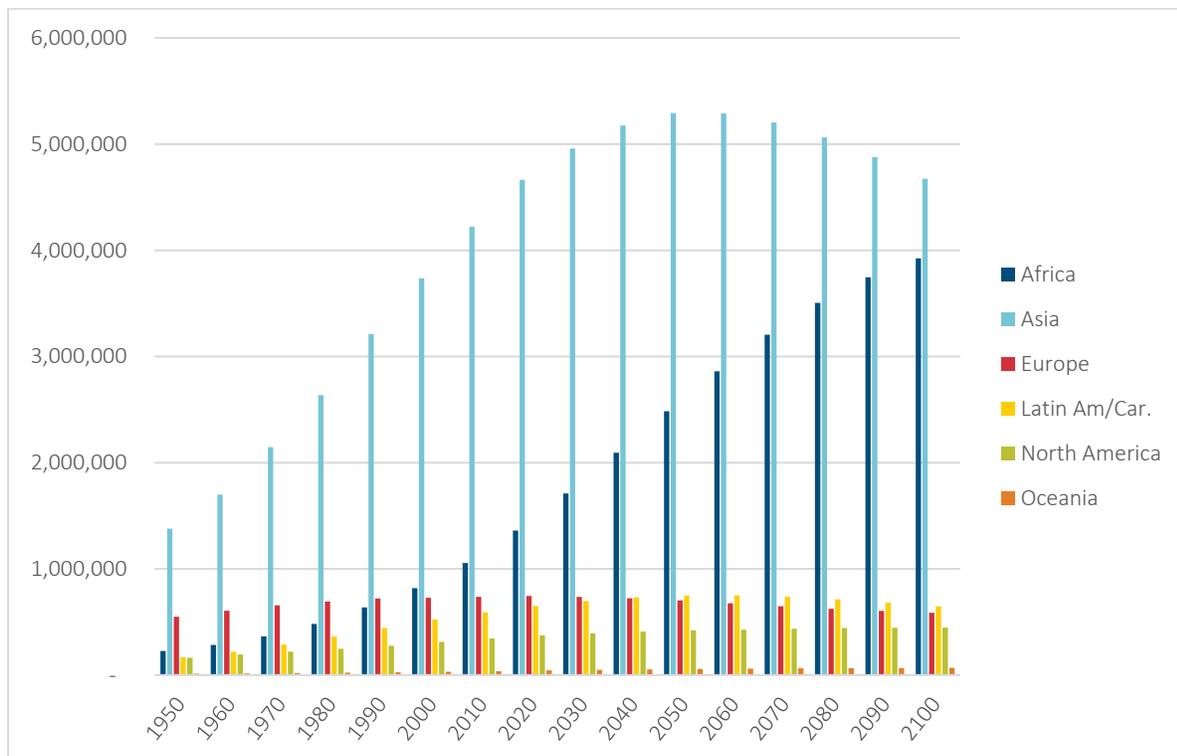
³⁶ Case, A. and Deaton, A. *Deaths of Despair and the Future of Capitalism*. Princeton University Press. 2020.

Section 4: Demographic Charts

Looking at projections of future global population levels comes with many caveats. Looking out very far ignores many potential events that could change (in either direction) the United Nations current global peak estimate in 2100 of 10.4 billion people. Much like economic measures, many population models assume smooth continuation of trends with no discontinuities along the way. Wars, famines, pandemics or other calamities are all aggregated into the historical data used to project. This does not mean it is not useful, and the United Nations population tool is very intuitive to use.³⁷

A demographics model that extends beyond 20 years provides information about a future that is already determined in many ways. Today's plans need to consider sensitivities to potential futures. This is demonstrated in Figure 13. The Asian population has been the largest by region since before 1950 but will be challenged by Africa as we near the end of the current century. Within the Asian region lie two behemoths that will diverge soon as China's population peaks and begins to shrink while India grows for another generation.³⁸ Contracting populations are typically aging populations with high old-age dependence ratios. Africa, led by sub-Saharan countries like Nigeria, will drive population growth in this century. It is notable that the remaining regions are unimportant relative to global totals. None of them reach 1 billion during this century.

Figure 13
GLOBAL POPULATION BY REGION (THOUSANDS)



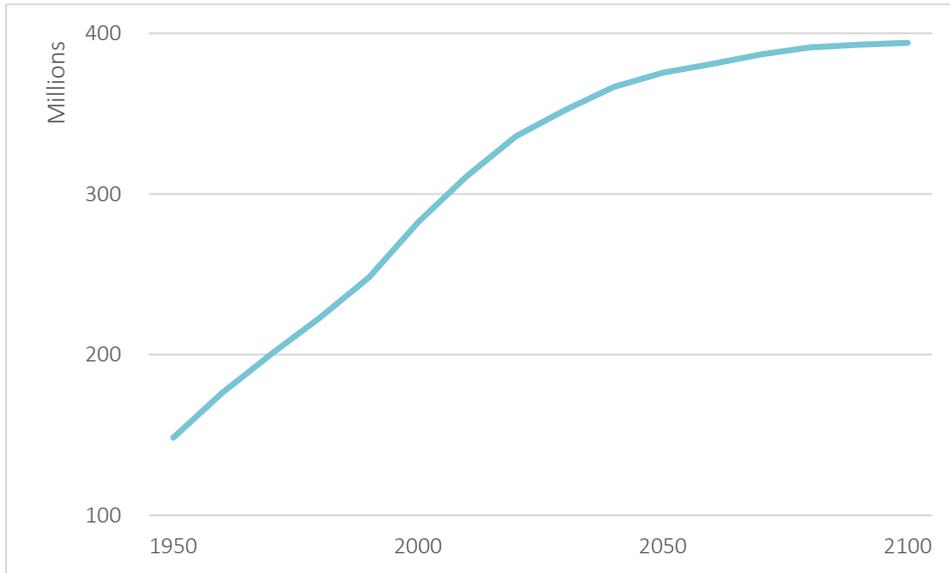
³⁷ <https://population.un.org/wpp/>

³⁸ Population Issues Working Group. *Actuarial Perspectives on World Population Prospects 2019*. International Actuarial Association. October 2020. https://www.actuaries.org/IAA/Documents/Publications/Papers/PIWG_Actuarial_Perspectives_World_Population_Pro Prospects_2019.pdf

United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Data Sources. (UN DESA/POP/2022/DC/NO. 9).

While many nations see their population peak prior to 2100, in the United States growth continues monotonically until 2050, and then stabilizes near 400 million, as seen in Figure 14.

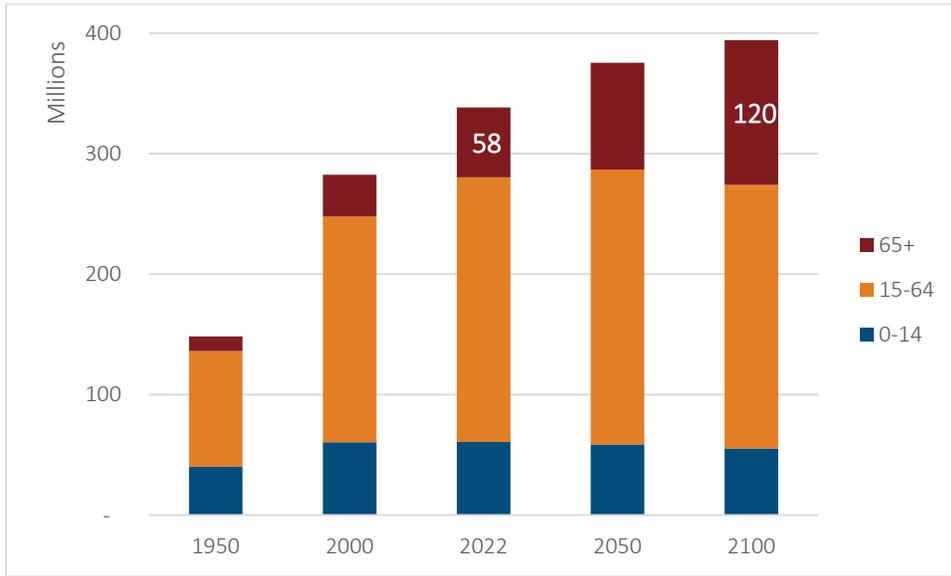
Figure 14
U.S. POPULATION PROJECTION



United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Data Sources. (UN DESA/POP/2022/DC/NO. 9).

Of growing importance in many countries during this century is the old-age dependency ratio. Figure 15 breaks down total U.S. population by age group from 1950 until 2100. The number of young and working age groups are relatively stable over the period from now to 2100, but the 65+ group more than doubles in size.

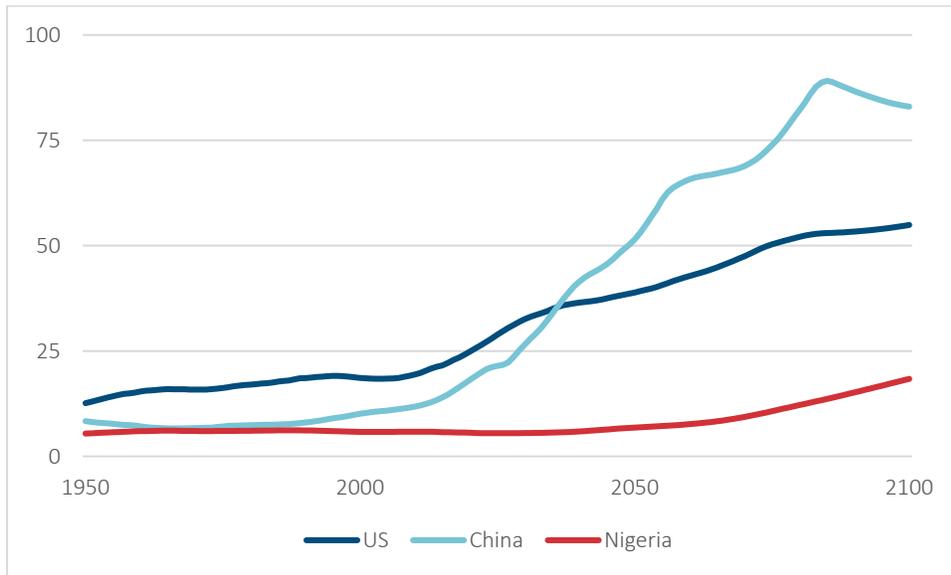
Figure 15
U.S. POPULATION BY AGE GROUPS



United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Data Sources. (UN DESA/POP/2022/DC/NO. 9).

Unsurprisingly, the large growth in the 65+ group with a flat growth in work force creates an increasing level of old-age dependency ratio as seen in Figure 16. To demonstrate differences, the countries of Nigeria, the United States and China are compared in Figure 16 using the ratio of 65+ per 100 in the work force.

Figure 16
OLD-AGE DEPENDENCY RATIOS PER 100 WORKERS (AGES 15-64) FOR SELECT COUNTRIES, 1950-2100



United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Data Sources. (UN DESA/POP/2022/DC/NO. 9).

Nigeria represents countries that are young and growing. It is not until 2060 that the old-age dependency ratio begins to materially rise in Figure 16 from a current level below six. Nigeria does not reach an old-age dependency ratio of 25 prior to 2100. Countries in this group will have an advantage over those with higher old-age dependency ratios as older populations slow economic growth.

In Figure 16 the United States represents a country with an old-age dependency ratio that has already begun its inevitable increase. From a current ratio of 25 the U.S. reaches 55 per 100 persons of working age by 2100. The U.S. actually lags many of its developed country peers who have already begun the aging process, including Japan and many countries in the European Union.

The elderly dependency ratio for China is driven by many factors. China is a large, aging, country that will impact global economics for many years. The one-child policy and other government programs have impacted its demographic trends. Old-age dependency ratio grows from 20 per 100 in the work force today to nearly 90 at its peak about 2085. Some of the UN scenarios reach a peak of nearly 150 65+ per 100 working, with uncertain ramifications to society. It is hard to imagine having more people retired than working or how that would smoothly be accomplished. This extreme relationship may lead to discontinuities due to political and economic reasons.

Surprises that lead to discontinuities could develop globally or for individual countries. Pandemics often attack specific age groups. The 1918 influenza pandemic impacted young workers so would increase dependency ratios. The COVID-19 pandemic initially increased mortality primarily among the old and those with comorbidities, decreasing the old-age dependency ratio. Wars with other countries tend to have a mortality impact on a country's younger population as young soldiers are sent to other countries and suffer injury and death. Wars that happen between enemies may impact mortality across all age groups in the location where battles occur, as both soldiers and others are at risk.

Section 5: Other Factors

There are other potential factors related to productivity and growth that could lead to future research projects. They include:

- The earth recently exceeded 8 billion people. Malthus focused on limitations on food production, but the ultimate issue seems to be finite resources. Human existence itself adds to water and food shortages, biodiversity loss, climate change, pollution and deforestation.³⁹ It also leads to a number of global reaching questions. How many people are too many? How can incentives between regions and countries be developed to manage population size that are fair and equitable? GDP slows during a recession, and those conditions are what Franklin noted as naturally slowing population increase. As an example, could tight monetary policy be allowed to slow growth globally and trickle-down benefits to sustainability?
- One of Robert Gordon's headwinds to growth is that women, as a subpopulation, have already entered the workforce. This boosted GDP levels during the last century during and following World War II. As a result, the productivity increase has already occurred. On a related note, this also creates a lack of resilience during wartime, when workers typically leave their jobs to be soldiers, and others must be found to take over those positions while the soldiers are away. What group of potential workers will come off the sidelines if the pool of available workers has diminished because greater numbers are already in the workforce?
- Climate change and pollution are not the only environmental concerns. There has been a reduction in biodiversity in the recent past and there are concerns that steep declines in certain fish, animal and insect populations may be imminent. These issues have financial implications and will impact local, regional and global economies.
- Many of today's climate scenarios rely on a concept called overshoot, where carbon emissions and temperatures rise beyond expectations prior to 2100 and carbon capture techniques are developed to reduce atmospheric and oceanic carbon. Current carbon capture methods are very expensive and will reduce expected GDP levels.
- Some have suggested a policy of degrowth, where GDP growth is negative. This would be a challenge from a psychological perspective as positive single digit growth is assumed to be normal. As populations stabilize or shrink a new understanding of what is normal, perhaps where the population and productivity components are separated, could be developed.
- Scenarios that include a population crash could be considered, either globally or regionally. This could be an especially lethal infectious disease, global crop failure due to a super volcano eruption, war or other natural or man-made calamity.
- Valuation of benefits payable after retirement, whether private defined benefit or social insurance like Social Security in the United States, are either designed to be fully funded at all points in time or a pay-as-you-go (PAYG) system. The PAYG design may become unsustainable when fertility rates are low and dependency ratios are increasing. This may cause some kind of disruption.

³⁹ Kuebler, Martin. *How can 8 billion people sustainably share a planet?* November 15, 2022. Deutsche Welle. <https://www.dw.com/en/how-can-8-billion-people-sustainably-share-a-planet/a-63729664>

Section 6: Potential Solutions

Deaths of despair have highlighted a changing picture of inequality, but improved outcomes in the lower socioeconomic classes could drive higher overall economic growth and improve resiliency. Creating a level playing field can help all groups to succeed.

GDP growth rate has typically been the metric of choice for economic growth, but peak population levels and concerns about incentives when GDP is used have created a desire to seek out alternative measures. A reduced population means fewer resources are used, generating fewer greenhouse gases. The GDP per capita metric offers adjustments for changes in population and the Happiness Index combines surveys with pure financial metrics to provide balance.

Recognizing that some countries will have high dependency ratios at the same time other countries are growing quickly and may have trouble keeping up with job opportunities for all of them, a potential approach for developed countries to consider is to seek out relationships with countries likely to provide immigrant labor. Creating those relationships in the near term, for example between European and sub-Saharan countries, may help with assessing long range population strategies.

Productivity typically grows through interactions between technology, education and resources. The marketplace has traditionally led to priorities on what is desirable and what needs to be done. The potential solutions provided here should be considered nudges against imperfect marketplace solutions.

There are many potential solutions to raise GDP growth that increase productivity, proactively plan for appropriate population levels or potentially both. Any such solutions may be more successful if they include impacted groups in their development and implementation, rather than involving them only post implementation. In previous attempts to develop financially sound infrastructures for local Black/African American communities, banks were created to serve these communities. Customers in the local communities placed their savings with these banks and used other banking services. But, some of these banks took these savings and loaned them out to areas outside of the local community.⁴⁰ This practice worked at odds with what was originally intended to make these local communities financially stronger. Instead, it contributed to further financial challenges within the bank's own local community, while making other areas stronger. Practices like these can run counter to building better opportunities and increased equity for local community members. Technological solutions such as those being developed in connection with FinTech may be a way to address this. Since FinTech companies are not limited in their operations by physical location, it may be easier to ensure access and equity across broader regions.

The following are some further potential approaches for addressing different aspects of GDP by category.

Grow Productivity

Subsidies have historically been used to support disadvantaged groups. Focusing on those who currently contribute the least to GDP, the lowest socioeconomic groups, through education, services, and infrastructure, can improve their socioeconomic status while contributing greater amounts to GDP totals.

⁴⁰ Baradaran, Mehrsa. *Color of Money: Black Banks and the Racial Wealth Gap*. 2017. The Belknap Press.

Optimize global population distribution

- Consider how global immigration can be managed better based on where people are needed, both within a country and internationally.
- Potentially develop a plan in advance for location of climate havens to better protect populations. Look for cross benefits between climate solutions and the health of communities. This includes projects that reduce the heat island effect (more green spaces can improve living conditions, employment and other opportunities for lowest socioeconomic groups) and pollution (low-income housing is often downwind of manufacturing plants) or near undesirable locations. The same areas often have both poor health and lower financial outcomes.
- Countries likely to need resources could consider developing relationships with countries expected to have surplus resources to better meet needs.

Combination

- Potential solutions that combine productivity and population growth include improvements in health care, child care and education, diet, and reduction in physical risks in lower socioeconomic communities.
- More healthy diets through education, subsidies, nudges, and incentives can improve the overall health of communities helping to further growth. A reduction of physical risks can also help to promote growth. One way to accomplish this is through a risk assessment of physical locations and implementing safeguards before a disaster hits.

Section 7: Conclusions

Gross domestic product has been formally calculated for nearly a century. Growth in GDP can be broken down between population growth and productivity growth. Upcoming global peak population levels make it important to view these components separately. By focusing on each piece, scenarios can be built covering a wide range of outcomes.

The Andrews team in Section 2.5 found a negative impact on equity prices and interest rates as the elderly population grows in relation to others. The scenario sets described in Section 2.6 expect growth in 2010-2060 in developed countries to be about half what it was in the 50 years ending in 2010. Demographics matter, and while the relationship is unlikely to be linear, scenarios that consider how to increase productivity or globally optimize population distribution may be considered proactively.

Neither Franklin nor Malthus discussed resource constraints in their theories. Similarly, sometimes decision-makers will apply an economic theory that assumes minimal resource constraints. Examples of such resource assumptions include pollution does no harm; potable water never runs out and pulling fossil fuels from the ground has no cost beyond the extraction process. Related to this, some bookkeeping practices may not consider such resource examples as a financial cost and minimize their financial implications. While some tax policies take this “tragedy of the commons” concept into account, for example as a carbon tax, it may not be consistently or transparently applied.

A healthy balance between biodiversity, environmental protections, climate solutions and economic growth can create a win-win scenario for humanity and the earth’s ecosystem.

Climate risk and resource depletion have shown that negative externalities can fall through the cracks in our accounting and incentive systems (e.g., no charges for pollution or water extraction), but that is not the only concern. An animal ecosystem relies on a predator/prey balance, but humans are not challenged except by pathogens or events like human warfare. A changing climate can increase the likelihood of food insecurity, but humans must provide their own discipline regarding access to land, water and other resources. These are problems that will need solutions.

Human ingenuity has provided pivots in practice to advance short-term sustainable practices. For example, the green revolution fed a generation of growth, but monoculture crops are now threatened by disease; greenhouse gas emissions are warming the planet with ramifications to every decision; and fish populations are at risk due to pollution, ocean acidification and overfishing. Scientists are developing techniques that add years to our lives and reducing childhood diseases, stressing these issues further as we live longer.⁴¹ GDP growth per capita needs solutions to these problems to avoid stagnation. Thinking about population and productivity as separate issues can help decision makers identify a variety of ways to marginally improve economic growth.

Civil rights and inequality appear to be tied to economics and productivity. Holding back specific groups slows economic growth for the whole but retains social safety net costs that have financial implications. Many communities today live in a services desert. Others live in urban heat islands developed by past redlining (less green space, more cement, lower economic development), with living spaces often made toxic by pollution. It comes down to incentives. Will practices be implemented that align the incentives necessary to reduce inequality?

⁴¹ Rudolph, Max. *Was Malthus Right, but Early?* Environmental Sustainability 2017 Call for Essays. Society of Actuaries. <https://www.soa.org/research/opportunities/environmental-essays.pdf>

Demographically, thinking about cycles can be useful when building scenarios. What could happen, what has happened in the past, and how can foresight be built into the process?⁴²

Implications for older populations are important because baby boomers are living longer, expanding the number of individuals using social insurance programs, while fertility rates are below replacement levels and migration has become a politically sensitive issue. Scenarios should be built independently for each country due to their unique demographic structures and projected futures.

Productivity can grow GDP even with a stable population if groups at the bottom of the socioeconomic ladder are incented to move up and more fully contribute to growth. This can likely be accomplished, in part, by righting wrongs against groups who have historically suffered from discrimination including such areas as banking, employment opportunities, and access to services.

Finally, demographic projections point to the global population level peaking during the current century, either by choice or because resources and food production cannot support this many people. GDP growth is normally driven first by population growth based on the metric currently used, but a more optimal distribution of population resources between and within countries can have a positive effect and increase GDP per capita.

Recent historical data is not always predictive. Examples include changes that may come about from climate developments or other varied changes such as new building codes and property locations. We have seen such examples in recent wildfires, hurricanes and the COVID-19 pandemic. Actuaries could work to develop improved extrapolation methods and encourage external stakeholders to recognize the importance of improved methodology, as foresight can improve resiliency of economic growth and company solvency.

7.1 KEY TAKEAWAYS

GDP growth is likely to be lower going forward than we are used to. There are methods to consciously manage this growth by improving productivity and optimizing population distribution. Here are some key takeaways from this paper:

- Global population is expected to peak at 10.4 billion (from the current 8), with regional differences and GDP growth about half what the previous generation became accustomed to.
- GDP growth is estimated by the sum of percentage population increase and percentage productivity increase.
- Older populations lower asset returns and lower GDP growth.
- Old-age dependency ratio is a useful metric to develop scenario plans of future GDP growth.
- Actions that improve outcomes for those in lower socioeconomic circumstances may have a positive impact on GDP through productivity gains.
- Countries that consider their immigration and emigration policies carefully may improve financial resilience.
- GDP growth should not be the only metric used when assessing growth and productivity. GDP per capita and the Happiness Index provide alternatives as population peaks and ecosystem limits are reached.

⁴² Werther, Dr. Guntram and Rudolph, Max. *Resurrecting the White Swan Mindset: How Much more can be forecast?* August 2021. Society of Actuaries. <https://www.soa.org/resources/research-reports/2021/resurrecting-white-swan/>

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