Population and Welfare: Measuring Growth when Life is Worth Living

Mohamad Adhami Mark Bils Charles I. Jones Peter J. Klenow *

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Abstract

Economic growth is typically measured in per capita terms. A long tradition in philosophy, however, suggests that social welfare may depend on the number of people as well. To illustrate how much this matters quantitatively, we decompose welfare growth — measured in consumption-equivalent (CE) units — into contributions from rising population and rising per capita consumption. Because of diminishing marginal utility from consumption, population growth is scaled up by a value-of-life factor that empirically averages nearly 3 across countries since 1960. Population increases are therefore a major contributor to growth if one takes a total utilitarian perspective.

*Adhami: Stanford University; Bils: University of Rochester, Richmond Fed, and NBER; Jones: Stanford GSB and NBER; Klenow: Stanford University and NBER. We are grateful to David Weil for a thoughtful discussion and participants at many seminars for comments. We thank Eugenio Gonzalez Flores, Tom Houlden, Kazuma Inagaki, Kyeongmin Park, and Liz Song for their excellent research assistance. An earlier version of this paper circulated under the title "Population and Welfare: The Greatest Good for the Greatest Number."

1. Introduction

How much progress is being made over time? Economic growth is almost invariably measured in *per capita* terms. The reason for this is clear: we seek to quantify gains in living standards, and individual consumption is a key argument of people's utility functions.

Consider however two hypothetical countries with the same time paths of total factor productivity (TFP). One keeps population constant, with TFP growth translating only to higher per capita consumption. The other keeps per capita consumption constant, expanding only its population. The per capita approach used by growth economists implies there was progress only in the first country despite the two having identical production possibilities.

This example conveys the importance of the metric used to measure progress. While growth economists have focused almost exclusively on per capita measures, philosophers have long debated the merits of the per capita versus total perspective. We are not going to resolve that long-standing debate — and indeed, we think the per capita approach is useful in many contexts. However, we find it valuable to ask: To what extent does adopting a total utilitarian criterion matter?

This paper reconsiders the pace of economic growth across countries using a consumption-equivalent (CE) metric based on a total utilitarian welfare criterion. Consider an economy of N_t identical people with consumption per person c_t and annual flow of individual utility $u(c_t)$. Under a total utilitarian criterion, social welfare is $N_t \cdot u(c_t)$. We show that consumption-equivalent social welfare growth is then given by:

$$v(c_t) \cdot g_{Nt} + g_{ct}$$

where g_N and g_c denote population growth and per capita consumption growth, respectively. The weight $v(c)$ on population growth is the value of a year of life measured as a ratio to per capita consumption.

A key challenge is valuing $v(c_t)$. We follow Hall, Jones and Klenow (2020) by calibrating $v(c_t)$ to a large literature that estimates the value of a statistical life (VSLY). These imply a $v(c_t)$ typically greater than one, reflecting the "consumer surplus" associated with life. For example, the VSLY in the United States in recent years is around \$185k while per capita consumption is around $38k, implying a ratio just under 5: a year of life is worth around 5x per capita consumption. For the world as a whole since 1960, we estimate a value of around 2.7. As a result, a percentage point of population growth is substantially more important than a point of growth in per capita consumption.

Inherent in our calibration is that lives are valued, per year, the same as individuals value longer lives. We can, of course, see reasons one might value later life more, e.g., reaping the benefits of investments in skills or relationships. But, just as obviously, youth has its benefits. Thus, we see our calibration as a natural alternative to the per capita approach of assuming $v(c_t) = 0$. Having said that, we do consider robustness of our results to lower values for $v(c_t)$ than implied by VSLY estimates. These can be viewed as showing robustness to valuing a year of life, on average, much less than willingness to pay to extend life.

Across the 101 countries in our sample, we find that consumption-equivalent welfare growth averages 6.2% per year between 1960 and 2019. In contrast, annual growth in per capita consumption averages 2.1%, so population growth accounts for two thirds of CE welfare growth. The growth rate of total utilitarian social welfare also provides a very different perspective on the progress of various countries over time. Mexico, South Africa, and Kenya move from the bottom third of growth rates to the top 60%. On the flip side, traditionally fast-growing countries like Germany, Japan, and China have much slower CE welfare growth because of slow population growth. Overall, the correlation between CE welfare growth and per capita consumption growth is 0.51, and the correlation with population growth is 0.29.

It is important to clarify what we are *not* doing in this paper. We perform a normative growth accounting exercise under a total utilitarian welfare function. Because we say nothing about the production side of the economy, we cannot make policy recommendations. We cannot address questions such as “Is the fertility rate too low?” or “Did the demographic transition raise or reduce social welfare?” Answering these questions requires estimating and incorporating externalities from pollution, ideas, and human capital. We consider this beyond the scope of our measurement effort. Of course, whether one uses a totalist approach as an ingredient will matter for many questions in addition to growth measurement. These include optimal fertility policy; assessing the welfare effects of adverse events such as the Black Death, HIV/AIDS (Young, 2005), and Covid-19; the welfare effects of China’s One Child policy; deciding what percent of GDP to devote to mitigating and adapting to climate change;

and how much to publicly invest in nonrival knowledge more generally (the benefits of which will increase in the size of the future population under totalist but not per capita approaches).

The remainder of the paper proceeds as follows. After a brief review of the literature, Section 2 lays out our basic theory and derives the expression for CE social welfare growth. Section 3 applies this framework to a broad set of countries over the period 1960 to 2019. Section 4 then explores the robustness of these results to alternative calibrations of preference parameters and goes over extensions allowing for inequality within countries and migration across countries. Section 5 relaxes the assumption that flow utility only depends on consumption. To do so, we write down a simple model featuring parental tradeoffs between per person consumption, leisure, fertility, and investments in children's human capital. Using time use data for the U.S., Netherlands, Japan, South Korea, Mexico, and South Africa, we conduct a model-based accounting exercise decomposing CE welfare growth into contributions from population growth and per-capita utility growth. Finally, Section 6 concludes.

Related literature. Harsanyi (1955) provides axioms under which a total utilitarian social welfare function orders allocations when the population is fixed. This axiomatic approach has been extended to consider variable populations by Broome (2004), Blackorby, Bossert and Donaldson (1995), McCarthy, Mikkola and Thomas (2020), and Gustafsson, Spears and Zuber (2023), among others. Kuruc, Budolfson and Spears (2022) survey this axiomatic literature. The takeaway is that, provided some technical conditions hold, three seemingly reasonable axioms imply a total utilitarian social welfare function with variable population. These are *same number Pareto* (the welfare ordering respects Pareto improvements among fixed populations), *non-anti-egalitarianism* (society does not prefer inequality), and *mere addition* (holding other individuals' utilities constant, adding a person who values living does not reduce social welfare).[1]

De la Croix and Doepke (2021) propose a "soul-based utilitarian" social welfare function that postulates a fixed number of souls who can be born or not, or even re-born. They show that this nests various other social welfare functions considered in the literature, including total utilitarianism. Chichilnisky, Hammond and Stern (2020) propose a related, survival-

[1]These axioms rule out welfare functions given by $W = N_t^{\alpha} \cdot u(c_t)$, for $\alpha < 1$. To see why, rewrite W as $W = N^{\alpha-1} \cdot Nu(c)$. So, adding 1000 people whose lives are worth living—but only slightly—could reduce welfare.

probability weighted social welfare function.

Parfit (1984) highlights the "repugnant conclusion" challenge to total utilitarianism. This challenge holds that maximizing total welfare could lead to extremely large populations of people whose lives are just barely worth living. For the purposes of this paper, we emphasize that our welfare calculations do not reflect arbitrary expansions of population, only the births and deaths of persons who actually lived between 1960 and 2019.

The per capita (or average) utilitarian approach also has well-known problems. For example, it implies that it is good to remove people whose lives are valuable but below average. It also implies that adding a small number of "tormented lives" with negative utility is preferable to adding a large number of lives with positive but small utility — the so called sadistic conclusion (Arrhenius, 2000).

As a measurement exercise, this paper does not have anything to add to either side of the philosophical debate. Instead, our results highlight that the stakes of this debate are high, in the sense that the two competing views offer markedly different perspectives on progress across countries. We see this as our main contribution, since earlier attempts at measuring growth across countries have primarily relied on the per capita approach.

Jones and Klenow (2016) incorporate consumption, leisure, life expectancy, and inequality in comparing standards of living across countries but focus on per capita comparisons. Cordoba (2015) explicitly analyzes how rising longevity offsets fertility reductions in terms of the growth of parental living standards. He uses a per capita approach but does incorporate how the quantity and quality of children affect parental welfare. He finds that declining fertility lowers welfare growth relative to standard per capita measures whereas we emphasize that positive rates of population growth raise welfare growth relative to those same measures.

The per capita and total approaches would also lead to different policy recommendations. Cordoba and Liu (2018) study optimal population in the presence of a fixed factor (land). This involves trading off fertility, which parents derive utility from, against lower land per capita and hence lower consumption per person. Córdoba and Liu (2022) analyze optimal allocations with a fixed factor and endogenous population, under both total and per dynasty welfare criteria. Golosov, Jones and Tertilt (2007) propose Pareto efficiency criteria for assessing outcomes when population levels are endogenous due to fertility choices, in contrast to our social welfare function approach. Finally, Eden and Kuruc (2023) consider the resourcedepleting effects of larger populations; these effects show up in consumption per person, so our measure implicitly includes such effects already.

2. The Framework: Aggregate Welfare

To make our point as clearly as possible, consider an economy of N_t identical people, each with consumption per person c_t.[2] Each person gets flow utility $u(c_t)$. The total flow of welfare enjoyed by this economy is then

$$W(N_t, c_t) = N_t \cdot u(c_t). \tag{1}$$

This is a standard total utilitarian social welfare function. Without loss of generality, the value of death is normalized to zero. For life to be valuable, it must then be that $u(c) > 0$. In addition, we make the standard assumptions that u exhibits diminishing marginal utility: $u'(c) > 0$, and $u''(c) < 0$.

Flow utility in (1) is in the spirit of GDP or consumption per capita in a given year. The present discounted value of flow utility would be of great interest, but is more difficult to assemble for many countries and would require speculative forecasts to calculate for current generations.

Consider the growth rate of social welfare:

$$\begin{aligned} dW_t &= dN_t \cdot u(c_t) + N_t \cdot u'(c_t) \cdot c_t \cdot \frac{dc_t}{c_t} \\ \Rightarrow \frac{dW_t}{W_t} &= \frac{dN_t}{N_t} + \frac{u'(c_t)c_t}{u(c_t)} \cdot \frac{dc_t}{c_t} \end{aligned}$$

Because the social welfare function is linear in N, the growth rate of welfare W_t is in "population units": the weight on population growth is one. We divide both sides so that the weight

[2] In subsection 4.2, we relax the assumption of a representative agent.

on consumption growth equals one to get consumption-equivalent (CE) welfare growth:[3]

$$\underbrace{\frac{u(c_t)}{u'(c_t)c_t} \cdot \frac{dW_t}{W_t}}_{\text{CE welfare growth}} = \underbrace{\frac{u(c_t)}{u'(c_t)c_t}}_{\equiv v(c_t)} \cdot \frac{dN_t}{N_t} + \frac{dc_t}{c_t} \tag{2}$$

This CE welfare growth is the rate at which consumption would need to grow under a constant population size to produce growth in welfare equal to the one resulting from the observed growth in population and per capita consumption. We focus on CE units for two reasons. First, it has become a standard welfare metric in macro and adjacent fields since Lucas (1987), with applications in business cycles (Krusell, Mukoyama, Şahin and Smith Jr, 2009), growth (Jones and Klenow, 2016), international trade (Arkolakis, Costinot and Rodríguez-Clare, 2012), and beyond. Second, it is in the same units and therefore easily compared to growth in per capita GDP.

Equation (2) puts population growth in consumption-equivalent units using the slope of the social indifference curve. It implies that a percentage point of population growth is worth $v(c_t)$ percentage points of consumption growth. Intuitively, the weight on population growth, $v(c_t) \equiv \frac{u(c_t)}{u'(c_t)c_t}$, is the value of having one more person live for one period, $u(c_t)$; dividing by the marginal utility of consumption puts this in consumption units, and then because we are comparing CE growth rates, we further divide by per capita consumption.[4]

Note $v(c)$ is the inverse of the elasticity of utility with respect to consumption. If $u(c) = c^\alpha$, then $v(c) = 1/\alpha$. With linear utility ($\alpha = 1$), $v(c) = 1$ and the value of a year of life equals per capita consumption. If $\alpha = 1/2$, $v(c) = 2$. Thus the sharper is diminishing marginal utility (the lower is α) the higher is $v(c)$. We expect $v(c) > 1$ to capture the "consumer surplus"

[3] In discrete time, one gets consumption-equivalent welfare growth by solving $W(N_t, c_t) = W(N_{t-1}, \lambda \cdot c_t)$. We use continuous time because, as the time interval shrinks to zero, the compensating variation equals the equivalent variation and we do not need to make this distinction. subsection A.1 provides the more formal derivation of this result.

[4] One could alternatively measure welfare growth in population-equivalent units simply by inverting by the slope of the indifference curve in equation (2). But the share of welfare growth due to population growth is invariant to that change in units:

$$\frac{v(c_t) \cdot g_{N_t}}{g_{\lambda_t}} = \frac{v(c_t) \cdot g_{N_t}}{g_{c_t} + v(c_t) \cdot g_{N_t}} = \frac{g_{N_t}}{\frac{g_{c_t}}{v(c_t)} + g_{N_t}} = \frac{g_{N_t}}{g_{\mu_t}}.$$

So our finding below that, from a total utilitarian perspective, population increases are a major contributor to growth is independent of the choice of units.

associated with diminishing marginal utility.

Measuring $v(c_t)$ The challenge when taking equation (2) to the data is how to assign values for $v(c_t)$. This requires taking a stance on how many percentage points of consumption growth a percentage point of population growth is worth.

Our approach leverages estimates of the value of a statistical life (VSL). These are based on the compensation in wages that an individual would require to be indifferent to facing a slightly higher probability of death. They provide a revealed preference valuation of increased life expectancy in units of consumption growth. In using such VSL estimates to calibrate $v(c)$, we are treating added life-years that reflect births as equally valuable to added years from rising longevity. The value of a marginal year of life, captured by VSL estimates, could exceed its average value, say due to experiences and relationships developed with age. But it could plausibly be less, reflecting reduced health.

This being said, in Section 4.1, we explore the robustness of our conclusions to using an average value of life that is lower than the marginal. Rather than valuing births and longevity differently, we do so by calibrating to a $v(c)$ that is lower than the range of marginal VSLY implied by the empirical literature. We follow this approach because the data required to separate population growth into contributions from births and longevity are available for only a subset of countries, as discussed in Section 4.4.

To determine the value of $v(c_t)$, we would ideally have VSL estimates from many different countries and time periods. There is limited well-identified evidence of this kind, so we take a different approach. Instead, we use available estimates for the U.S. in recent years and extrapolate to other years and countries using a specific functional form for flow utility.

$v(c)$ for the United States in 2006. The U.S. Environmental Protection Agency (2020) uses a VSL equal to \$7.4m in 2006 prices. A middle-aged American had a remaining life expectancy of around 40 years in 2006, so this corresponds to a value of statistical life year (VSLY) of around \$185,000.[5] Consumption per person in the United States in 2006 was \$38,000, includ-

[5]For simplicity, we are not discounting here. With discounting and growth in consumption, the numbers are similar; see Jones and Klenow (2016).

ing both private consumption and government consumption, which implies:

$$v(c_{us,2006}) \equiv \frac{u(c)}{u'(c)\cdot c} = \frac{\text{VSLY}}{c} = \frac{\$7,400,000/40}{\$38,000} = \frac{\$185,000}{\$38,000} = 4.87\,.$$

That is, a year of life in 2006 in the United States is valued at approximately 5 years worth of consumption per person.

The VSL estimate we use is in line with the value of life used elsewhere. For example, the U.S. Department of Transportation (2014) suggests efficacy of safety regulations should be evaluated considering VSL's over a range of $4 to $10 million for the U.S. in 2001. In subsection 4.1, we consider robustness to VSL values of 50% and 150% of our baseline.

Calibrating $v(c)$ for other years and countries. Our benchmark for flow utility is

$$u(c_t) = \bar{u} + \log c_t.$$

With this functional form, the value of a year of life is given by

$$v(c_t) \equiv \frac{u(c_t)}{u'(c_t)\cdot c_t} = u(c_t) = \bar{u} + \log c_t. \tag{3}$$

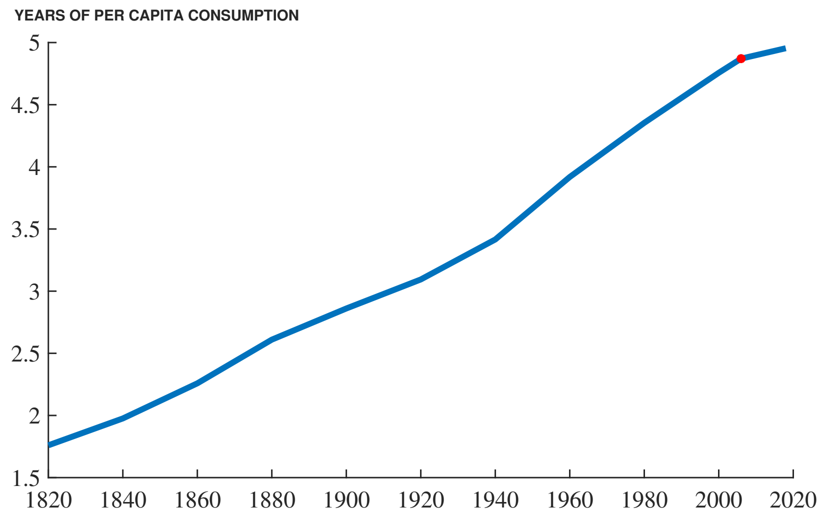
Both of these equations make clear the importance of the constant term $\bar{u}$. To calibrate its value, we choose consumption units such that $c_{us,2006} = 1$, which means that $v(c_{us,2006}) = \bar{u} = 4.87$.

The other interesting thing to note about $v(c)$ from equation (3) is that it is not constant. In particular, $v(c)$ increases with the log of consumption: as living standards increase, life becomes increasingly valuable, even relative to consumption.

Using data from the National Income and Product Accounts back to 1929 and from de Pleijt and van Zanden (2020) before that, Figure 1 shows the implied value of life $v(c)$ for the United States over time. As anticipated by equation (3), this value rises roughly linearly over time, reflecting the exponential growth in consumption. The value is slightly below 2 in 1820 and rises to nearly 5 by 2019.

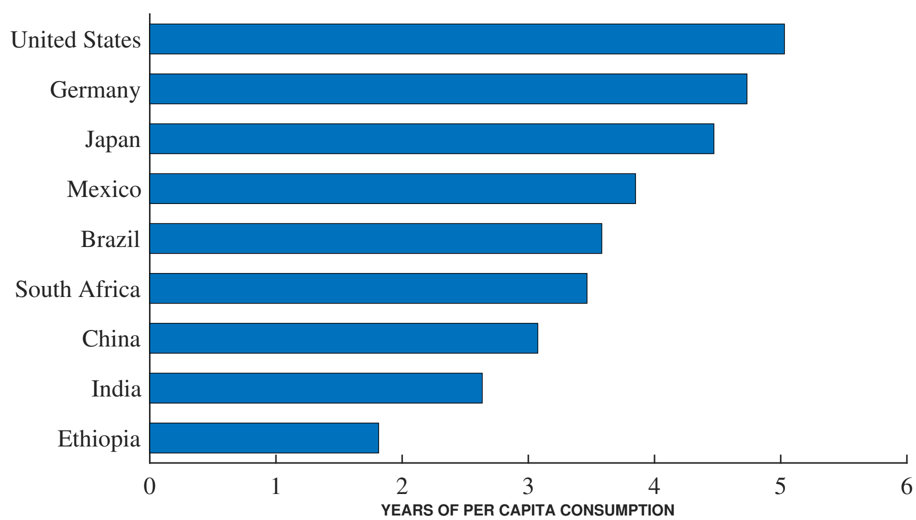
Figure 2 shows the values of $v(c)$ for some of the most populous countries in the world in 2019 using the Penn World Table 10.0. Interestingly, the range of values in the world's cross

Figure 1: $v(c)$ over time in the United States



Note: $v(c)$ computed using log utility and data from the U.S. National Income and Product Accounts back to 1929 and from de Pleijt and van Zanden (2020) with a constant consumption share of GDP before that.

Figure 2: $v(c)$ across countries in 2019



Note: $v(c)$ computed using data from the Penn World Tables 10.0 assuming log utility.

section for 2019 is similar to the historical U.S. values back to 1820, ranging from a low of just under 2 for Ethiopia to the high of 5 for the United States. The average value across 101 countries in 2019 is 2.7.

While our calibration strategy just targeted the U.S. in 2006, our $v(c)$ values are broadly consistent with the World Health Organization thresholds of one to three times per capita GDP for determining the cost effectiveness of spending to reduce mortality in developing countries (WHO, 2001; Kremer et al., 2023). These thresholds imply a range of about 1.5 to 4.5 times per capita consumption, not far from our range of 2 to 5 reported in Figure 2. Given the mixed evidence on the elasticity of $v(c)$ with respect to income, we consider alternative functional forms for flow utility in Section 4.

Summary. Consumption-equivalent social welfare growth, g_λ, is the sum of per capita consumption growth and population growth, where population growth is scaled by the value of a year of life relative to consumption, $v(c)$:

$$g_\lambda = v(c) \cdot g_N + g_c. \tag{4}$$

Population growth is valued according to how individuals themselves value living. Because $v(c)$ is in the range of 2 to 5, population growth gets a much higher weight than consumption growth. This contrasts with using aggregate consumption ($v = 1$) and with the per capita approach, which implicitly values lives at zero ($v = 0$).

The remainder of the paper applies (4) empirically. We use annual data and then average the result over longer time periods.[6] We see this as the best way to treat the data given the changing $v(c_t)$ over time. It is closest to our continuous-time derivation and allows us to avoid the usual "CV" versus "EV" discrepancy.

3. Results: Consumption-Equivalent Social Welfare Growth

For 1960–2019, we use the Penn World Table 10.0, an updated version of Feenstra, Inklaar and Timmer (2015), which gives us a sample of 101 countries. Consumption is calculated as the

[6]When annual data are not available, specifically in looking at data back to the 1500s, we interpolate between observations assuming a constant growth rate, then proceed as if we have annual data.

Table 1: Overview of Results from 1960 to 2019

	Unweighted	Pop Weighted
CE-welfare growth, g_λ	6.2%	5.9%
Population term, $v(c)g_N$	4.1%	3.1%
Consumption term, g_c	2.1%	2.8%
Population growth, g_N	1.8%	1.6%
Value of life, $v(c)$	2.7	2.3
Pop share of CE-welfare growth	66%	51%

Notes: In 77 of the 101 countries, the population share of CE welfare growth exceeds 50%.

sum of private consumption and government consumption.[7]

3.1 Macro Results for 1960 to 2019

Table 1 summarizes our results for the 101-country sample from the Penn World Table, applying equation (4) annually and taking the average. While growth in consumption per person averages 2.1% per year between 1960 and 2019, CE welfare growth is substantially higher at 6.2% per year. Growing at 2.1% per year, average living standards double every 33 years. But taking into account population growth as well, social welfare doubles every 12 years in this sample. The 4.1 percentage point difference between consumption growth and social welfare growth is accounted for by the fact that population growth averages 1.8 percent per year and the value of life $v(c)$ over this period has an average value equal to 2.7 years of consumption (covariances mean that the average of the product, 4.1 percent, is not equal to the product of these averages). Population growth accounts for 66% of social welfare growth on average across the 101 countries; weighting countries by their population, which gives China a large role, the population share of welfare growth falls to 51%.

Table 2 reports the decomposition of growth in consumption-equivalent social welfare for a select sample of countries based on equation (4). To begin, consider the countries with the

[7] The PWT has consumption data for 111 countries since 1960, but we drop any country labelled by the dataset as an outlier in any of the sample years.

Table 2: Decomposing Welfare Growth in Select Countries, 1960–2019

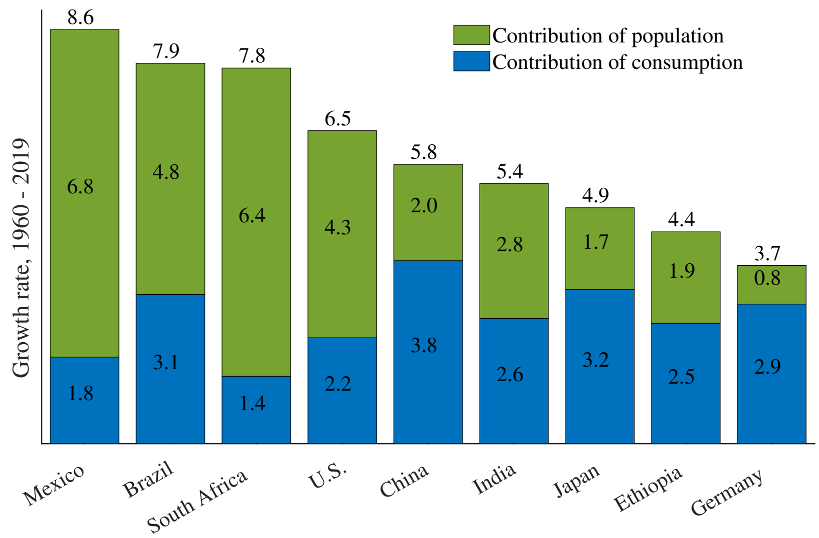
	g_λ	g_c	g_N	$v(c)$	$v(c) \cdot g_N$	Pop Share
Mexico	8.6	1.8	2.1	3.4	6.8	79%
Brazil	7.9	3.1	1.8	2.8	4.8	61%
South Africa	7.8	1.4	2.1	3.1	6.4	82%
United States	6.5	2.2	1.0	4.4	4.3	66%
China	5.8	3.8	1.3	1.8	2.0	34%
India	5.4	2.6	1.9	1.6	2.8	52%
Japan	4.9	3.2	0.5	3.8	1.7	34%
Ethiopia	4.4	2.5	2.7	0.7	1.9	44%
Germany	3.7	2.9	0.2	4.0	0.8	22%

Notes: g_λ denotes consumption-equivalent social welfare growth, g_c is the growth rate of per capita consumption, g_N is population growth, $v(c)$ is the value of life year relative to consumption, and the population share is $v(c) \cdot g_N / g_\lambda$.

fastest and slowest growth in the table. Social welfare growth in Mexico averages 8.6% per year since 1960, far exceeding its modest growth in consumption per person of 1.8% per year. This is for two reasons: population growth averages more than 2% per year and Mexico's value of life factor $v(c)$ averages 3.4. Population growth accounts for 79% of social welfare growth in Mexico. At the other extreme is Germany. Its relatively higher growth rate of consumption is barely augmented by its very modest population growth of 0.2% per year even though its value of life factor is 4.0. Population growth accounts for just 22% of social welfare growth in Germany. Figure 3 shows these data graphically, in part to make comparisons with later figures easier.

To show results for a broad set of countries, Figures 4 and 5 present scatterplots of CE welfare growth against consumption growth and population growth. The range of variation in CE welfare growth is striking. Even the slowest-growing countries have growth rates of CE welfare between 1960 and 2019 that exceed 2% per year. This constrasts with the negative consumption growth rates observed for a handful of countries. Equally striking is the fact that the fastest-growing countries have average annual growth rates of CE welfare that exceed 10% per year, versus a maximum of 5% per year for consumption growth.

Figure 3: Welfare Growth in Select Countries, 1960–2019



Notes: The numbers in the bars are CE welfare growth, the percentage point contribution from population growth, and per capita consumption growth. Data are from the Penn World Tables 10.0, an updated version of Feenstra, Inklaar and Timmer (2015).

Figure 4: Plot of CE growth against consumption growth, 1960-2019

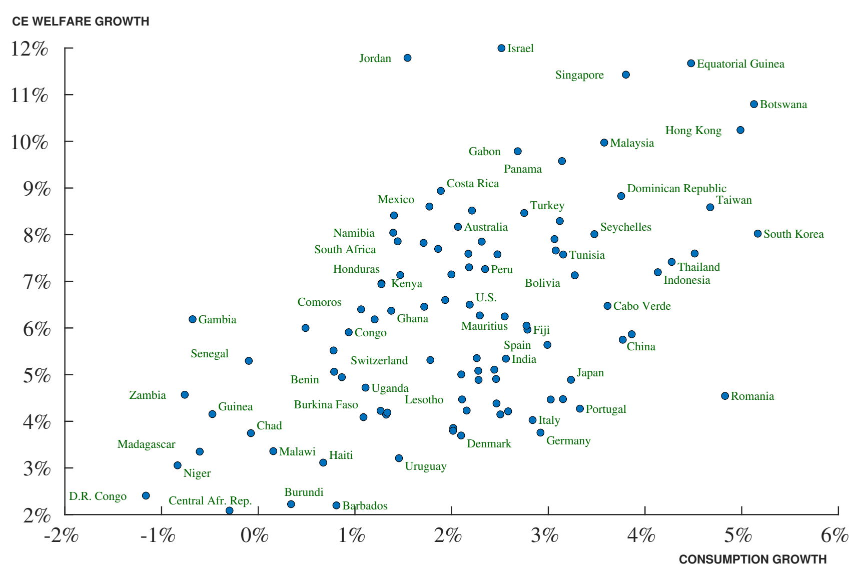
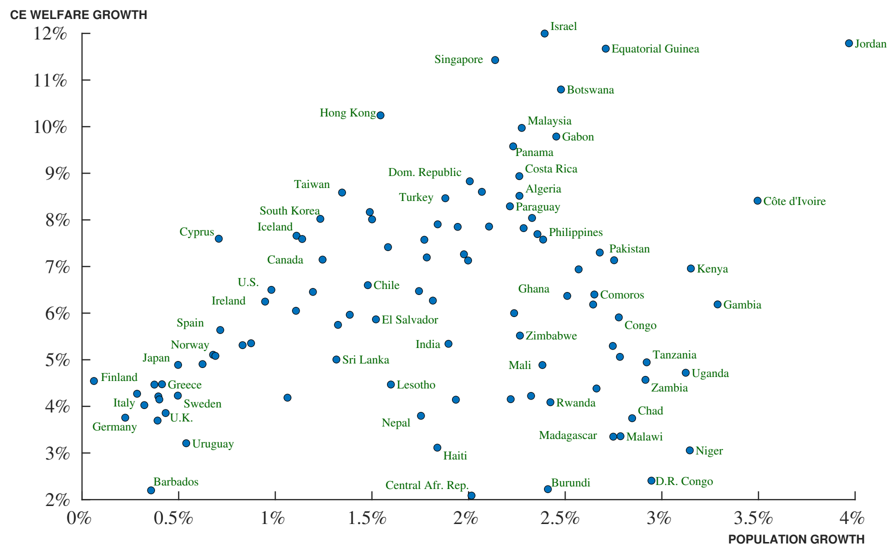


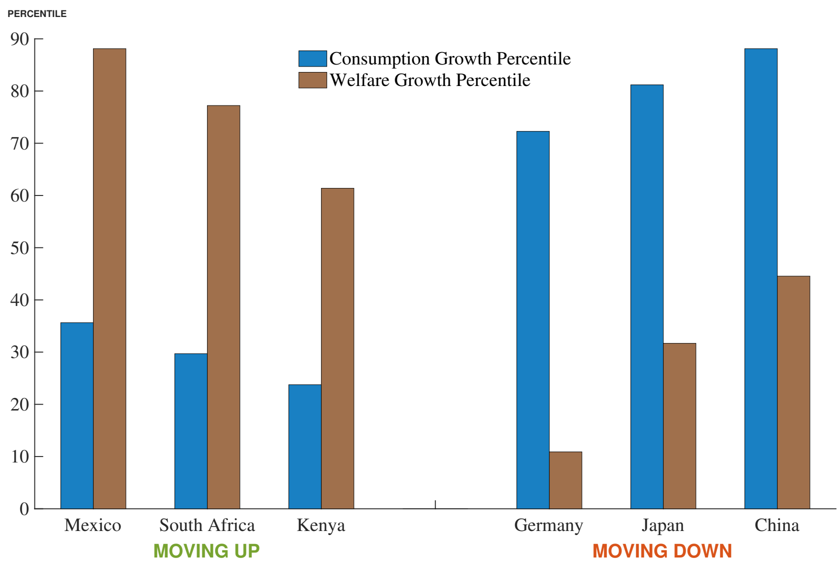
Figure 5: Plot of CE growth against population growth, 1960-2019



Neither consumption growth nor population growth are extremely correlated with CE welfare growth. The correlation with consumption growth is 0.51, while the correlation with population growth is 0.29.

Figure 6 provides a different way of illustrating the difference between our CE welfare growth and standard consumption growth measures by ranking countries from fastest to slowest growing. For example, China, Japan, and Germany are among the fast-growing countries over this period in terms of consumption growth, with China at around the 90th percentile. Slow population growth in these countries moves them sharply down in the distribution of CE welfare growth, with Germany falling to just the 11th percentile and China falling to the 44th percentile. In contrast, a number of countries with slow consumption growth move up sharply in the distribution. Mexico rises from the 35th percentile to the 88th, and Kenya rises from the 23rd percentile to the 61st.

Figure 6: Changing Perspectives on Who is Growing Rapidly



Notes: The chart shows the percentile in the cross-country distribution of growth rates between 1960 and 2019 for a select set of countries. Data is from the Penn World Tables 10.0.

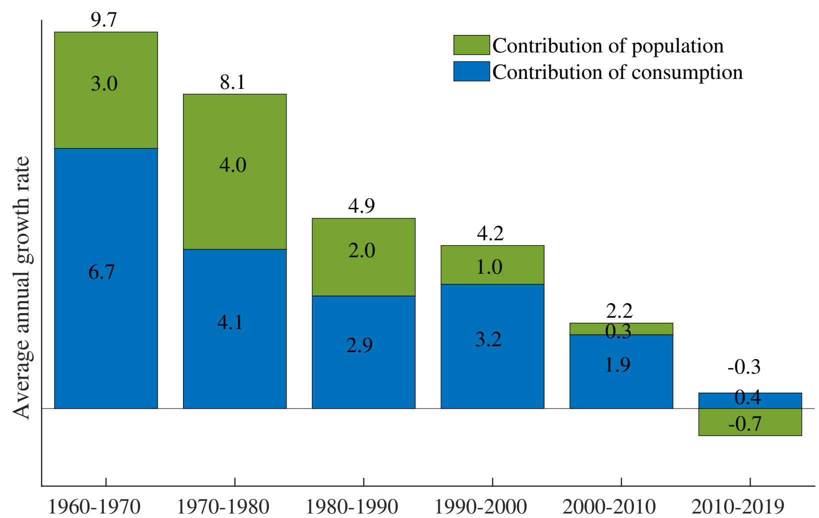
3.2 Growth Rates in Sub-Periods

Figure 7 shows CE welfare growth in Japan by decade since 1960. The well-known slowdown in Japanese growth is evident in the contribution from consumption growth. This slowdown is reinforced by declining rates of population growth. CE welfare growth slows from 9.7% per year in the 1960s to -0.3% in the 2010s. For this most recent decade, a negative population growth rate of -0.15% per year — when scaled up by $v(c)$ — more than offsets the modest consumption growth rate of 0.4%.

Figure 8 shows growth in China since the 1960s. Population growth in China (not shown) slows from 2.3% per year in the 1960s to just 0.5% per year in the 2010s. The rising value of life $v(c_t)$ helps offset this decline: the contribution of population growth to CE welfare growth falls from just 2.2% per year in the 1960s to 1.5% per year in the 2010s. CE welfare growth has slowed since the 1990s, but the decline is modest, from 7.0% per year to 5.7% per year.

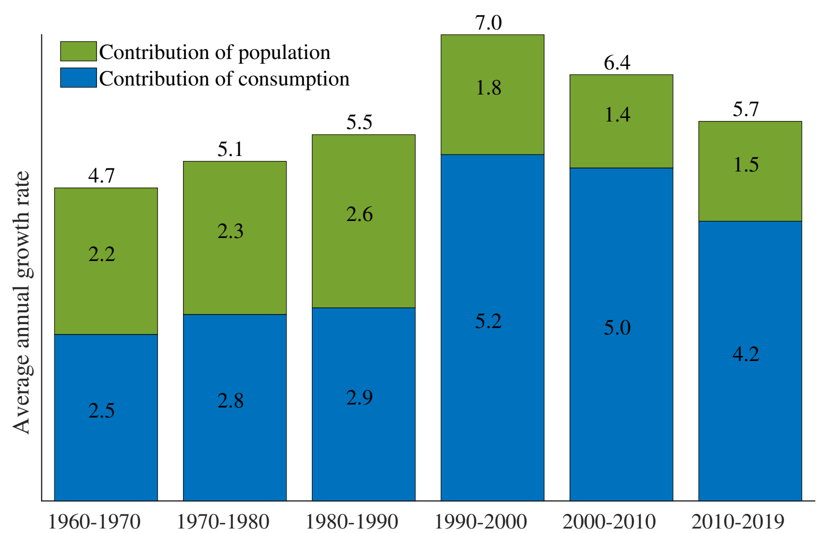
In contrast, the bulk of CE welfare growth in Sub-Saharan Africa since the 1960s has been due to population growth, as shown in Figure 9. Population growth was relatively stable at

Figure 7: Growth in Japan by Decade



Notes: The numbers in the bars are CE welfare growth, the percentage point contribution from population growth, and per capita consumption growth.

Figure 8: Growth in China by Decade



Notes: The numbers in the bars are CE welfare growth, the percentage point contribution from population growth, and per capita consumption growth.

just over 2.5% per year during the entire period, and the population term accounts for around 4pp of CE welfare growth in Sub-Saharan Africa each decade. Consumption growth rose in the 2000s and 2010s, leading to a robust CE welfare growth rate of more than 8% in the 2010s.

3.3 Growth over the Very Long Run

Figure 10 shows the gain in CE welfare for the world as a whole since 1500 using data from The Maddison Project (de Pleijt and van Zanden, 2020). Over more than five centuries, consumption per person rises by a factor of 20, corresponding to average growth of 0.6% per year. Population growth is similarly modest at just 0.5% per year, but the cumulative effect on welfare is stunningly different: CE welfare rises by a factor of 3,700 versus the 20-fold increase in per capita consumption. The average annual growth rate of CE welfare is just a percentage point higher, at 1.6% per year instead of 0.6% per year, but such is the power of compounding for 500 years.

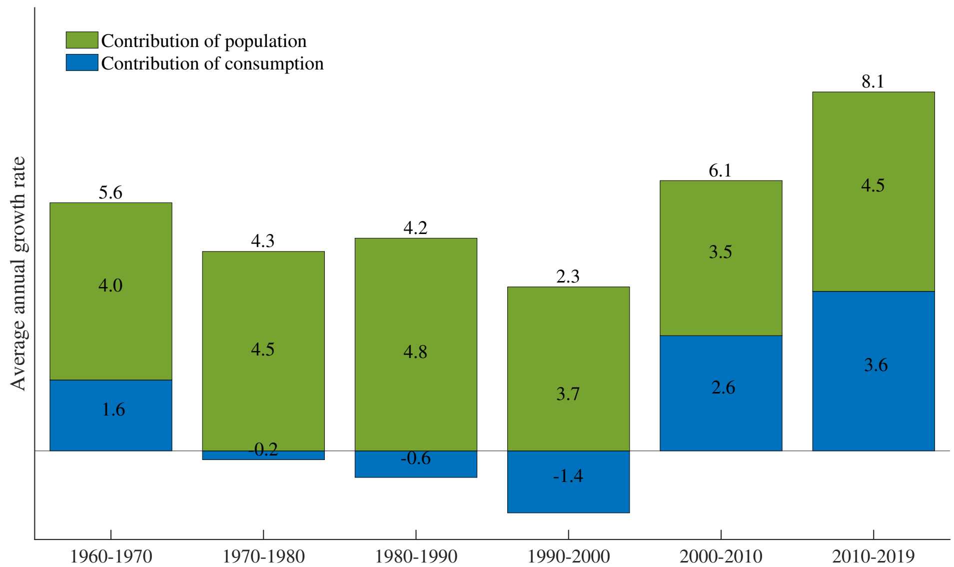
4. Robustness

In this section we first explore robustness of the results above with respect to our baseline parameter choices for preferences. These parameters dictate the valuation of life and, hence, the importance of population growth for welfare. We then examine how our country-by-country results are affected by allowing for within-country heterogeneity in consumption and by considering alternative treatments of population changes reflecting cross-country migration. The final subsection examines the respective contributions of fertility versus longevity.

4.1 Parameters governing the value of life

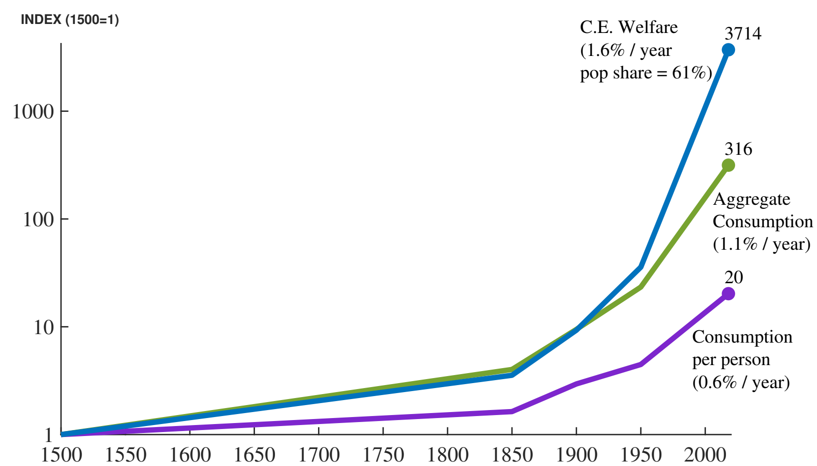
Table 3 demonstrates the sensitivity of CE welfare growth, on average and in select countries, to alternative calibrations of parameters determining the value of life. We report per capita consumption growth in the first row to highlight the contribution of population growth across different specifications. While the growth rates are sensitive to parameter values, we consistently find that population growth is a major contributor to welfare growth, so that the total utilitarian approach offers a different perspective on the pace of progress across countries.

Figure 9: Growth in Sub-Saharan Africa by Decade



Notes: The numbers in the bars are CE welfare growth, the percentage point contribution from population growth, and per capita consumption growth.

Figure 10: Cumulative Growth in "The World," 1500–2018



Note: Data from The Maddison Project data of de Pleijt and van Zanden (2020). We estimate consumption as 0.8 times per capita GDP for this figure.

Table 3: CE welfare growth for Different Parameter Values, 1960–2019

	Mean	U.S.	Japan	Mexico	Ethiopia
1. Per capita consumption	2.8	2.2	3.2	1.8	2.5
2. Baseline	5.9	6.5	4.9	8.6	4.4
3. $\gamma = 2/3$	15.8	7.3	6.3	14.5	30.4
4. $\gamma = 2$ for U.S. in 2006	4.5	5.5	4	5.1	3.4
5. Constant $v = 4.87$	10.6	7.0	5.7	11.8	15.4
6. Constant $v = 2.7$	7.1	4.8	4.6	7.4	9.7
7. Constant $v = 1$	4.4	3.2	3.7	3.8	5.1
8. $\text{VSL}_{\text{US},2006}$ 50% lower	4.4	4.2	4.0	4.8	3.5

Notes: Entries are average annual percentage growth rates. “Mean” refers to the population-weighted mean across countries. Given the $c_{us,2006} = 1$ normalization, $v(c_{\text{US},2006}) = \bar{u}$ for each of our robustness checks. Baseline corresponds to $\gamma = 1$, $\bar{u} = 4.87$, and variable $v(c)$. The fourth and eighth rows use a variable curvature functional form under which γ is increasing in c.

Values for the CRRA parameter γ. Our baseline uses a log utility function in consumption. We consider the sensitivity of our results to alternative CRRA functions:

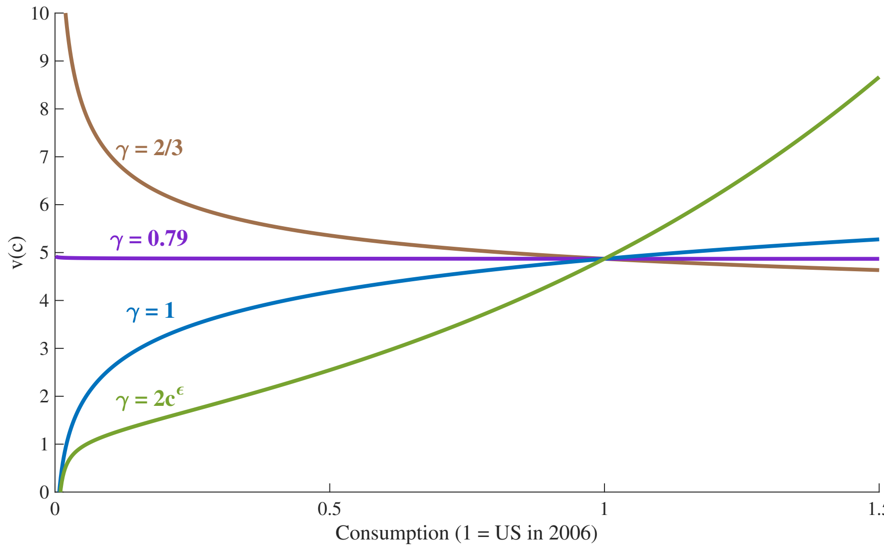
$$u(c) = \bar{u} + \frac{c^{1-\gamma} - 1}{1-\gamma} \implies v(c) = \left(\bar{u} - \frac{1}{1-\gamma}\right) c^{\gamma-1} + \frac{1}{1-\gamma}. \tag{5}$$

Note that $v(c)$ is a function of γ. Whereas the U.S. value for $v(c)$ in 2006 is calibrated independently of γ, how $v(c)$ evolves over time and across countries depends on γ.

Figure 11 illustrates that, relative to $\gamma = 1$, lower γ's yield higher values for $v(c)$ in the past and for countries poorer than the U.S. Therefore, lower γ's imply a higher weight on population growth in our sample. This is why, in row 3 of Table 3 ($\gamma = 2/3$), we get faster growth than in our baseline, and especially so for poorer countries. In this case, the contrast with the per capita perspective is even starker.

In contrast, higher γ's yield lower values for $v(c)$ in the past and for countries poorer than the United States. With $\gamma = 2$, $v(c)$ is negative in 1960 for 84 of the 101 countries in our sample. As emphasized by Weil (2014) and Cordoba and Ripoll (2016), these extrapolated values are hard to reconcile with estimated statistical life values in poorer countries. Thus, to entertain more curvature in utility while maintaining non-negative value of life for countries

Figure 11: $v(c)$ for different values of γ



Notes: Different $v(c)$ are shown for different values of γ, but all curves are calibrated to match the U.S. value of life in 2006 at $c = 1$; that is, all have $\bar{u} = 4.87$. The $\gamma = 2c^{\epsilon}$ line corresponds to $\gamma(c) = 2c^{\epsilon}$ with $\epsilon = 0.6$ so that $\gamma = 2$ in the U.S. in 2006, while maintaining positive $v(c)$ across countries in our sample.

in our sample, we assume that the coefficient of relative risk aversion is an isoelastic function of consumption $\gamma(c) = 2\,c^{\epsilon}$. This is consistent with $\gamma = 2$ for the U.S. in 2006 ($c = 1$). The resulting $v(c)$ is:

$$v(c) = \frac{\exp\left(-\frac{2}{\epsilon}\right)\ \bar{u} - F(1) + F(c)}{\exp\left(-\frac{2}{\epsilon} \cdot c^{\epsilon}\right)\ c} \qquad \text{where} \qquad F(y) \equiv \int_0^y \exp\left(-\frac{2}{\epsilon} \cdot x^{\epsilon}\right)\, dx\,.$$

We set $\bar{u} = 4.87$ to get $v(c) = 4.87$ for the U.S in 2006 and $\epsilon = 0.6$ to get $v(c) = 0$ at the lowest consumption level in our sample.[8] Figure 11 plots the resulting $v(c)$ as a function of c. Calculations based on this specification are in row 4 of Table 3. While the growth rates are lower than in the baseline (due to lower weight on population growth), we continue to find that the total utilitarian approach offers a different perspective on the pace of progress across countries, and population remains an important contributor to welfare growth in most countries.

[8]This level, for Zimbabwe in 1995, is 0.97% of U.S. consumption in 2006.

Figure 11 illustrates that $v(c)$ is decreasing in c for $\gamma = 2/3$, but increasing in c for $\gamma = 1$ and $\gamma = 2c^{\epsilon}$. Evidence on the income elasticity of the value of life is mixed. Viscusi and Aldy (2003) conduct a meta analysis of more than 40 studies and conclude that the income elasticity is typically less than one, suggesting that $v(c)$ may decline with consumption. On the other hand, Hammitt, Liu and Liu (2000) and Costa and Kahn (2004) use within-country panel evidence and arrive at income elasticities greater than one. Meanwhile, Kremer, Leino, Miguel and Zwane (2011) obtain estimates of the VSL for Kenya that are very low compared to estimates of the VSL in the U.S., consistent with an income elasticity greater than one.

Yet another alternative is for $v(c)$ to be independent of c, corresponding to an income elasticity of the value of life equal to one. Weil (2014) argues that this is a reasonable interpretation of the evidence. Similarly, thresholds for VLSY used by the WHO (2001) imply an income elasticity of one across developing countries. This motivates us to consider cases where $v(c)$ is independent of c. From equation (5), $v(c)$ independent of c requires that parameters γ and $\bar{u}$ be related: $\gamma = 1 - \frac{1}{\bar{u}}$. This, in turn, implies $v(c) = \bar{u}$. Row 5 of Table 3 sets $v = 4.87$ for all country-years, corresponding to our calibrated target for the U.S. in 2006; row 6 sets $v = 2.7$ in all country-years, corresponding to the average v across country-years in our baseline calculation; and row 7 sets $v = 1$ in all country-years. When $v = 1$ in all country-years, CE welfare growth simply equals aggregate consumption growth.

A common $v = 4.87$ generates much more growth in CE welfare, as it raises $v(c)$ in all country-years to be that of the U.S. in 2006. A common $v = 2.7$ generates average welfare growth close to that in our baseline. But it also generates larger differences in the growth rates across countries: CE welfare growth is slower in the U.S., Japan, and Mexico but faster in Ethiopia. The final row shows that, even in the extreme case where CE welfare growth equals aggregate consumption growth ($v = 1$, $\gamma = 0$), population growth contributes 36% of all growth.

Calibration of $\bar{u}$. In our baseline calculation, we set $v(c) = 4.87$ in the U.S. in 2006 (U.S. Environmental Protection Agency, 2020). Given the wide range of estimates in the empirical literature, we consider an alternative calibration targeting a VSL that is half the baseline, requiring $\bar{u} = 2.4$. For comparison, the U.S. Department of Transportation (2014), based on a review of the literature, suggests that safety regulations should be evaluated using VSL's over a range of \$4 to \$10 million for the U.S. in 2001. The range we consider maps to a VSL of \$2.8 to \$5.7 million for 2001, so is rather conservative relative to the DOT's recommendations.

Targeting a lower VSL with $\bar{u} = 2.4$ while maintaining $\gamma = 1$ leads to negative $v(c)$ in 1960 for 67 of the 101 countries in our sample. So, again we assume the coefficient of relative risk aversion is an isoelastic function of consumption $\gamma(c) = c^{\epsilon}$. This is consistent with $\gamma = 1$ for the U.S. in 2006 ($c = 1$) as in the baseline.[9] The results of this robustness check are in final row of Table 3.

4.2 Heterogeneity and Inequality

The framework from Section 2 assumes a representative agent within each country. However, heterogeneity could be important. For example, what if population growth occurs disproportionately among the poor so that a value of life based on average consumption overstates the value of adding people? In this section, we incorporate consumption inequality.

Consider an economy of N_t individuals who potentially differ in their consumption. The total flow of welfare for this economy is:

$$W_t = \sum_{i=1}^{N_t} u(c_{it}) .$$

We derive consumption-equivalent welfare (CEW) growth assuming log utility and a log-normal distribution of consumption across individuals. That is, we assume:

$$u(c_{it}) = \widetilde{u} + \log c_{it}, \text{ where } \log c_{it} \overset{\text{i.i.d.}}{\sim} \mathcal{N}\left(\log c_t - \frac{1}{2}\cdot\sigma_t^2 , \sigma_t^2\right),$$

where c_t is average consumption per capita. This then implies:

$$W_t = N_t \cdot \left(\widetilde{u} + \log c_t - \frac{1}{2}\cdot\sigma_t^2\right) .$$

[9] The resulting $v(c)$ is:

$$v(c) = \frac{\exp\left(-\frac{1}{\epsilon}\right)\ \bar{u} - G(1) + G(c)}{\exp\left(-\frac{1}{\epsilon}\cdot c^{\epsilon}\right)\ c} \qquad \text{where} \qquad G(y) \equiv \int_0^y \exp\left(-\frac{1}{\epsilon}\cdot x^{\epsilon}\right)\, dx .$$

We calibrate $\bar{u} = 2.4$ to get $v(c) = 2.4$ for the U.S in 2006 (50% lower than baseline) and $\epsilon = 0.34$ to get $v(c) = 0$ at the lowest consumption level in our sample.

Consumption-equivalent welfare growth is then given by (see subsection A.2):

$$g_{\lambda_t} \;=\; \left(\widetilde{u} + \log c_t - \frac{1}{2}\cdot\sigma_t^2\right)\cdot g_{N_t} \;+\; g_{c_t} \;-\; \sigma_t^2\cdot g_{\sigma_t}. \tag{6}$$

To illustrate the generality of equation (6) versus baseline equation (4), consider a scenario where births in country A skew towards lower-income households acting, ceteris paribus, to lower consumption growth and raise consumption inequality. Equation (4) captures its impact on growth in A's average consumption, while equation (7) also captures any impact through consumption inequality.

Our calibration above for $\bar{u}$ was based on an average VSL in the U.S. for 2006. With inequality, those estimates for VSL, and in turn $\bar{u}$, should be interpreted to reflect both the mean and dispersion in consumption in the U.S. in 2006. This implies $\widetilde{u}$ and $\bar{u}$ are related by $\widetilde{u} = \bar{u} + \frac{1}{2}\sigma^2_{US,2006}$. Substituting this expression into the preceding equation gives:

$$g_{\lambda_t} \;=\; \left(v(c_t) - \frac{1}{2}\cdot\left(\sigma_t^2 - \sigma^2_{\text{US, 2006}}\right)\right)\cdot g_{N_t} \;+\; g_{c_t} \;-\; \sigma_t^2\cdot g_{\sigma_t}, \tag{7}$$

where $v(c_t) = \bar{u} + \log c_t$ is the value of life based on average consumption used earlier.

Equation (7) highlights two ways in which introducing within-country heterogeneity changes our calculation. First, due to consumption heterogeneity and the concavity in $u(c)$, the weight on population growth is modified. For example, relative to our baseline, the weight is lower for country-years with greater consumption inequality than the U.S. in 2006. Second, there is an additional term through which increases in consumption inequality reduce CEW growth.

We implement this inequality-adjusted calculation in Table 4 for a sample of 90 countries between 1980 and 2007.[10] Overall, taking into account within-country heterogeneity lowers consumption-equivalent welfare growth by 10 basis points, from 6.1% to 6.0%, with an average absolute adjustment of 18 basis points. For some countries, the adjustment is sizable: Our baseline methodology understates welfare growth in Brazil because of the falling inequality over this period, but overstates growth in South Africa, which has greater inequality than the U.S in 2006.

[10]Data on consumption inequality in each of these countries are from Jones and Klenow (2016).

Table 4: Baseline vs Inequality-Adjusted CE welfare growth, 1980–2007

	Baseline	Inequality Adjusted	Adjustment
Ethiopia	2.1%	2.4%	0.27%
Brazil	7.1%	7.3%	0.15%
Japan	4.1%	4.1%	-0.05%
Mexico	7.0%	6.9%	-0.09%
United States	7.1%	7.0%	-0.13%
Germany	2.4%	2.2%	-0.13%
China	6.7%	6.6%	-0.15%
India	5.8%	5.7%	-0.16%
South Africa	7.7%	6.8%	-0.83%
All countries – pop. weighted	6.1%	6.0%	- 0.10%
Mean absolute deviation			0.18%

Notes: The table reports average consumption equivalent welfare growth using our baseline framework (equation 4) and adjusting for inequality (equation 7).

4.3 Taking Migration into Account

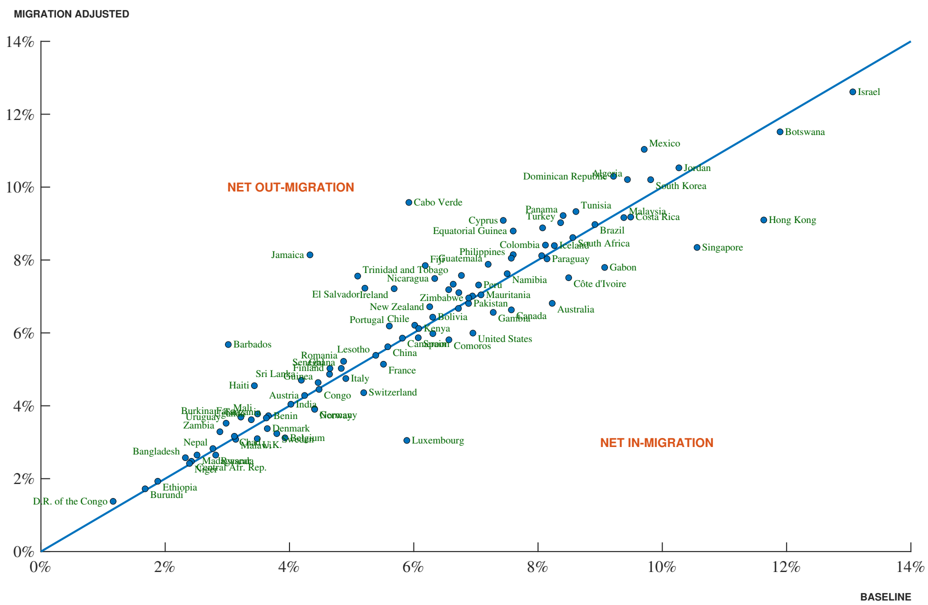
Our calculations to this point credit countries for the growth in the number and standard of living of its resident populations. This makes no distinction based on where the individuals were born and consequently assigns the contribution of migrants to their destination country. Taking the other extreme, one might instead attribute people to the country in which they are born. Compared to our baseline calculation, we can add flow utility for out-migrants and subtract flow utility from in-migrants:[11]

$$W_{it} = N_{it} \cdot u(c_{it}) + \sum_{j \neq i} N_{i \to j,t} \cdot u(c_{jt}) - \sum_{j \neq i} N_{j \to i,t} \cdot u(c_{it}),$$

where $N_{i \to j,t}$ is the population born in country i and living in country j in year t and $N_{j \to i,t}$ is the population born in country j living in country i in year t.

[11]An intermediate treatment would be to give countries credit for the higher consumption enjoyed by in-migrants from poorer countries.

Figure 12: Baseline vs. Migration-Adjusted CEW growth



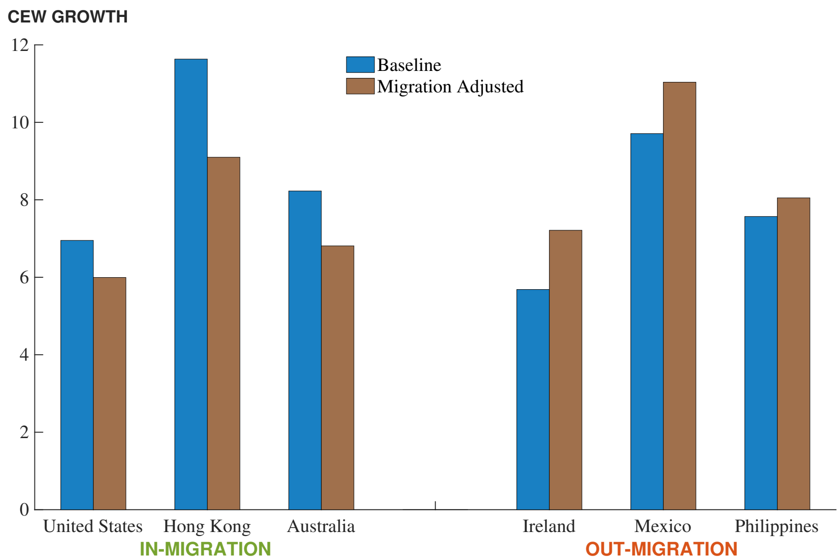
Growth in country welfare adjusted for migration is then

$$
\begin{aligned}
g_{\lambda_{it}} = \; & v(c_{it}) \cdot g_{N_{it}} \; + \; g_{c_{it}} \\
& + \sum_{j \neq i} \frac{N_{i \to j,t}}{N_{it}} \cdot \frac{u(c_{jt})}{u(c_{it})} \left(v(c_{it}) \cdot g_{N_{i \to j,t}} + \frac{v(c_{it})}{v(c_{jt})} \cdot g_{c_{jt}} \right) \\
& - \sum_{j \neq i} \frac{N_{j \to i,t}}{N_{it}} \left(v(c_{it}) \cdot g_{N_{j \to i,t}} + g_{c_{it}} \right). \qquad (8)
\end{aligned}
$$

The first term is our baseline, which credits all immigrants to the *destination* country. The second term adds in growth from out-migrants, and the third term subtracts growth from in-migrants. This adjusted measure therefore credits migrants to the *source* country.

To implement this migration adjustment, we use data from the World Bank's Global Bilateral Migration Database that reports the shares of each country's resident population by their country of origin for select years (1960, 1970, 1980, 1990, and 2000). With this data we can adjust for migration for 81 countries.

Figure 13: Countries with Large Migration Adjustments



The chart shows key countries for which the migration adjustment is large.

Figure 12 plots migration-adjusted welfare growth versus our baseline welfare growth for the 81 countries from 1960 to 2000. The points are close to the 45 degree line as results with and without the migration adjustment are highly correlated at 0.92. While the adjustments are sizable for certain countries, it does not alter the important role for welfare growth assigned to population growth. Figure 13 shows a set of countries for which the adjustment particularly raises welfare growth due to high net in-migration or lowers it due to high net out-migration.

4.4 Roles of Birth and Death Rates

From Table 1, population growth contributed CEW growth of about 3pp per year. That population growth reflects rates both of countries' births and deaths. Prior papers have quantified the importance of rising longevity for welfare, including Nordhaus (2002), Becker, Philipson and Soares (2005), Murphy and Topel (2006), Hall and Jones (2007), and Jones and Klenow (2016). For instance, Jones and Klenow attribute consumption-equivalent growth of nearly one percent per year to rising longevity for a sample of 128 countries for 1980 to 2007. That

Table 5: Population Growth Holding Longevity Constant

Select countries	g_N	Counterfactual g_N
France	0.61%	0.42%
UK	0.41%	0.25%
Italy	0.33%	0.08%
Japan	0.51%	0.15%
USA	1.03%	0.89%
All countries – pop. weighted	0.72%	0.53%

sample differs considerably from ours in terms of countries and time period considered. But comparing their 1 percent growth rate, ascribed purely to rising longevity, to our 3 percent suggests that increases in the number of persons living a life has contributed even more to welfare growth than has increased longevity.

To examine this in more depth, in the Online Appendix we compare countries' actual rates of population growth to counterfactual rates had each experienced no decline in death rates by age over the sample period. We construct these counterfactuals for 24 of our countries with data on birth and death rates from the Human Mortality Database combined with that on net migration from the World Bank's Global Bilateral Migration Database.

In Table 5 we report the actual versus fixed-longevity rates of population growth for five select countries and the aggregating the 24 countries by their populations. With fixed longevity, population growth falls from 0.72% to 0.53%. So nearly three-quarters of population growth for these countries reflected increases in the number of lives lived. Italy and Japan are clear outliers, with increasing longevity explaining about three quarters of population growth for each. Results for all 24 countries are in the Online Appendix.

5. Beyond Consumption

A limitation of our baseline approach is that our flow utility only incorporates consumption. Parents have kids because they presumably enter their utility function (Barro and Becker, 1989; Cordoba, 2015), but this is absent from our baseline. In addition, our baseline specification of flow utility does not incorporate leisure.

We therefore extend our framework in this section to incorporate parental fertility decisions that trade off altruism toward their kids (their consumption and human capital) with their own parental consumption and leisure time. Our treatment here mirrors Cordoba (2015), who measures effective growth rates, going beyond consumption, to capture the impact of changes in longevity and fertility as valued by Barro and Becker (1989) parents. The key difference is that we embed the exercise in a total utilitarian measure of welfare growth, whereas the approach in Cordoba (2015) is per-capita, or more accurately per dynasty.

5.1 Framework

Suppose the flow of social welfare takes the form:

$$W(N_t^p,\, N_t^k,\, c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t) \;=\; N_t^p \cdot u\left(c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t\right) \;+\; N_t^k \cdot \widetilde{u}(c_t^k)\ ,$$

where N^p is the number of adults ("p" for parents), N^k is the number of children ("k" for kids), b is number of children per adult, c^p is adult consumption, l is adult leisure, c^k is consumption per child, and h^k is human capital per child. Total population satisfies $N = N^p + N^k = (1+b)\cdot N^p$.

This is still a total utilitarian social welfare function. Specifically, welfare is the sum of all parents' flow utility (from their own consumption, their own leisure, their kids' consumption during childhood, their kids' human capital, and their number of kids) and all kids' flow utility. The fact that the consumption, human capital, and number of kids affect parental utility is reminiscent of Barro and Becker (1989) and Farhi and Werning (2007). Such parental altruism is necessary to explain why parents have kids and invest resources in them. We make kids' flow utility a function of their consumption only. We have in mind that kids' leisure is fixed at one, so it is suppressed, and that kids will enjoy the benefits of their human capital in the form of higher consumption when they are themselves adults.

To calculate consumption-equivalent welfare growth, we ask by what factor λ_t one has to scale up parents' and kids' consumption at t to match the flow utility at $t+dt$ given the changing numbers of parents and kids and per capita variables:

$$W(N_t^p, N_t^k, \lambda_t \cdot c_t^p, l_t, \lambda_t \cdot c_t^k, h_t^k, b_t) \;=\; W(N_{t+dt}^p, N_{t+dt}^k, c_{t+dt}^p, l_{t+dt}, c_{t+dt}^k, h_{t+dt}^k, b_{t+dt}).$$

Growth in consumption-equivalent welfare is:

$$g_{\lambda_t} = \kappa_t \Bigg[\omega_t^p \left(\frac{dN_t^P}{N_t^P} + \frac{u_{c_t^p} c_t^p}{u_t} \frac{dc_t^p}{c_t^p} + \frac{u_{l_t} l_t}{u_t} \frac{dl_t}{l_t} + \frac{u_{c_t^k} c_t^k}{u_t} \frac{dc_t^k}{c_t^k} + \frac{u_{h_t^k} h_t^k}{u_t} \frac{dh_t^k}{h_t^k} + \frac{u_{b_t} b_t}{u_t} \frac{db_t}{b_t} \right) \\ + \omega_t^k \left(\frac{dN_t^K}{N_t^K} + \frac{\tilde{u}'(c_t^k) c_t^k}{\tilde{u}(c_t^k)} \frac{dc_t^k}{c_t^k} \right) \Bigg]. \tag{9}$$

ω_t^p and ω_t^k are the total welfare shares of parents and kids in year t; κ_t translates this welfare into consumption-equivalent units; and $u_t = u\left(c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t\right)$.[12] This expression puts population growth, as well as growth in each of leisure, number of children, and human capital per child in consumption-equivalent units. The resulting CE welfare growth metric is the rate at which consumption would need to grow under constant population size and per-capita variables (other than consumption) to produce growth in social welfare equal to the one resulting from the observed growth in population and per capita utility.

We assume parental decisions are privately optimal. This allows us to follow the tradition of TFP accounting by measuring the relative weights on the factors in welfare by their costs in terms of parental time, which we take from time use surveys. Specifically, we assume that parents solve the following problem:

$$\begin{aligned} \max_{c^p,\, l,\, c^k,\, h^k,\, b} \quad & u(c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t) \\ \text{subject to:} \quad & c_t^p + b_t \cdot c_t^k \leq w_t \cdot h_t \cdot l_{c_t} \\ & h_t^k = f(h_t \cdot e_t) \\ & \text{and } \; l_{c_t} + l_t + b_t \cdot e_t \leq 1\,, \end{aligned}$$

where w is the real wage per unit of human capital, h is parental human capital, h^k is kids' human capital, l_c are parental hours worked, and e is parental time investment per child. Parents spend their earnings on their own consumption and their kids' consumption. Kids' human capital is an increasing function of their parents' human capital and their parents' time investment in them. Parents have a unit of time to allocate across work, leisure, and time with their kids.

[12] Derivation of this expression is in subsection A.3 of the appendix.

In order to map relative weights in our growth accounting to observables, we make the following assumptions:

Assumption 1: $u(c_t^p,\ l_t,\ c_t^k,\ h_t^k,\ b_t) = \log(c_t^p) + \alpha b_t^\theta \cdot \log(c_t^k) + \tilde{f}(l_t, h_t^k, b_t)$

Assumption 2: $\widetilde{u}(c^k) = \bar{u}_k + \log(c_t^k)$,

where $\tilde{f}(\ell_t, h_t^k, b_t)$ is a concave increasing function. In Assumption 1, parameters $\alpha > 0$ and $\theta > 0$ govern parental altruism towards their kids. In the special case $\alpha = 1$ and $\theta = 1$ parents are total utilitarians with respect to their own family. The literature often considers cases with $\alpha < 1$ and $\theta < 1$ (Doepke and Tertilt, 2016). Assuming these functional forms, growth in consumption-equivalent welfare is:

$$
\begin{aligned}
g_{\lambda_t} \ =\ & \pi_t^p \cdot v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \cdot g_{N_t^p} \ +\ \pi_t^k \cdot \tilde{v}(c_t^k) \cdot g_{N_t^k} && \text{Population} \\
& +\ \pi_t^p \cdot g_{c_t^p} \ +\ (1 - \pi_t^p) \cdot g_{c_t^k} && \text{Consumption} \\
& +\ \pi_t^p \cdot \frac{u_{l_t}\ l_t}{u_{c_t^p}\ c_t^p} \cdot g_{l_t} && \text{Leisure} \\
& +\ \pi_t^p \cdot \frac{u_{b_t}\ b_t}{u_{c_t^p}\ c_t^p} \cdot g_{b_t} && \text{Quantity of kids} \\
& +\ \pi_t^p \cdot \frac{u_{h_t^k}\ h_t^k}{u_{c_t^p}\ c_t^p} \cdot g_{h_t^k} && \text{Quality of kids}
\end{aligned}
$$

where

$$
\pi_t^p = \frac{N_t^p}{(1+\alpha b_t^\theta) N_t^p + N_t^k} \quad ; \quad \pi_t^k = \frac{N_t^k}{(1+\alpha b_t^\theta) N_t^p + N_t^k} \quad ;
$$

$$
v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) = \frac{u\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)}{u_c^p\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \cdot c_t^p} \quad ; \quad \tilde{v}(c_t^k) = \frac{\tilde{u}(c_t^k)}{\tilde{u}'(c_t^k) \cdot c_t^k}. \tag{10}
$$

The first line in the CEW growth expression is the new version of the "population growth" term. This population term differs from the simple $g_N \cdot v(c)$ specification in previous sections for several reasons. First, parents' value of a year of life v and kids' value of a year of life $\widetilde{v}$ may differ. Second, the value of a year of life for parents depends not only on their own consumption but also on their kids' consumption, their own leisure, their own fertility, and their kids' human capital. Third, we have a scaling factor of less than one in front of each non-consumption term. The intuition for this is that consumption, and hence the λ factor, enters welfare directly via the consumption of parents and kids, but also indirectly because parents value consumption of their kids' (the αb_t^θ term). Since consumption matters through this added channel, its growth becomes more heavily weighted vis-a-vis population growth.

The remaining lines in the CEW growth expression are the new version of the "per capita growth" term. It now includes growth in leisure, kids' human capital, and fertility along with growth in consumption per parent and per kid. Note that the weight on parent terms π_p is *less than* the share of parents in the population, and the corresponding weight on kids' consumption growth $1 - \pi_p$ exceeds the share of kids in the population. This likewise reflects parental altruism, which results in "double counting" (upweighting) the growth of kids' consumption. This point was emphasized by Caplin and Leahy (2004), Farhi and Werning (2007), and Eden (2024).

Illustrative example. A special case of this growth accounting is helpful for intuition. Suppose $\alpha = 1$ and $\theta = 1$, parents are total utilitarians for their own family, which implies $\frac{dc^k}{c^k} = \frac{dc^p}{c^p}$. Secondly, evaluate growth at a point where the value of a year of life happens to be the same for parents and kids, $\widetilde{v}(c_t^k) = v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)$ and denote it simply by $v(c_t)$. Then CEW growth becomes

$$\begin{aligned} g_{\lambda_t} \;=\; & g_{c_t} + \frac{N_t^p + N_t^k}{N_t^p + 2N_t^k} \cdot v(c_t) \cdot g_{N_t} \\ & + \frac{N_t^p}{N_t^p + 2N_t^k} \cdot \left(\frac{u_{l_t} l_t}{u_{c_t} c_t} \cdot g_{l_t} + \frac{u_{b_t} b_t}{u_{c_t} c_t} \cdot g_{b_t} + \frac{u_{h_t^k} h_t^k}{u_{c_t} c_t} \cdot g_{h_t^k} \right). \end{aligned}$$

Note the 2 multiplying N_t^k in the denominators on all terms other than consumption growth. The double counting of kids' consumption (their own utility and their parents' utility from it) means that a given increase in consumption per capita now leads to a greater increase in welfare. Taking into account this altruism effect downweights all non-consumption terms: consumption is now more valuable so we need to scale it up by less to capture its social welfare equivalent resulting from growth in the number of people, leisure, et cetera.

5.2 Implementation

Parents' first order conditions map weights in our growth accounting to observables:

$$\text{FOC}(l_t): \quad \frac{u_{l_t} l_t}{u_{c_t^p} c_t^p} = \frac{w_t h_t l_t}{c_t^p}, \tag{11}$$

$$\text{FOC}(b_t): \quad \frac{u_{b_t} b_t}{u_{c_t^p} c_t^p} = b_t \frac{(c_t^k + w_t h_t e_t)}{c_t^p}, \tag{12}$$

$$\text{FOC}(h_t^k): \quad \frac{u_{h_t^k} h_t^k}{u_{c_t^p} c_t^p} = b_t \frac{1}{\eta_t} \frac{w_t h_t e_t}{c_t^p}, \text{ where } \eta_t = \frac{f'(h_t e_t) h_t e_t}{f(h_t e_t)}. \tag{13}$$

Equation (11) says that that the weight on leisure growth should be tied to the marginal rate of substitution between consumption and leisure, which equals earnings relative to consumption. Equation (12) connects the weight on fertility growth to the marginal rate of substitution between fertility and consumption. The latter can be assessed using total spending on kids (including foregone earnings due to time spent investing in kids' human capital) relative to adult consumption. Equation (13) indicates that the weight on human capital growth is related to the marginal rate of substitution between human capital and consumption, which equals implicit spending on kids' human capital relative to adult consumption.

Data. Consumption and total population are from the Penn World Table 10.0. The number of children (0-19 years old) is from the World Bank. We combine data on total hours worked (Penn World Table) and on working-age population (World Bank) to calculate hours worked per adult. We measure parental time investments in kids using data on childcare from time use surveys. Leisure is then the residual after subtracting hours worked and total childcare from waking time, which we set equal to 16. Finally, to obtain growth in human capital, we assume an even split of real wage growth between human capital and real wage per unit of human capital. The most stringent requirement is the availability of consistent time-use surveys. Such data were available for the following country-years: United States (2003-2019), Netherlands (1975-2006), Japan (1991-2016), South Korea (1999-2019), Mexico (2006-2019), and South Africa (2000-2010).[13]

[13]The Online Appendix provides further details on the construction of different variables and how we implement the calculations.

Calibration. To calibrate the parameters governing parental altruism towards their kids, α and θ, we rely on a USDA study (Lino, 2011) of spending on kids versus parents within households. Note that, under Assumptions 1 and 2, the first-order conditions from the parents' utility maximization problem imply:

$$\frac{c_t^k}{c_t^p} = \alpha b_t^{\theta-1}.$$

For example, for $\theta = 1$ and $\alpha = 1$ parents equate each kid's consumption to their own. From Lino (2011), households with two parents and two children, for whom $b = 1$, spend approximately two-thirds as much on the children as the parents. From this we calibrate $\alpha = 2/3$. By contrast, two-parent household with one child spend somewhat more *per* child; those with three children spend somewhat less. These patterns are consistent with a value for θ of about 0.8, so we set $\theta = 0.8$.

The weight given to a child's human capital growth partly reflects the elasticity of a child's human capital with respect to parental input: $\eta_t = \frac{f'(h_t e_t) h_t e_t}{f(h_t e_t)}$. We impose a constant η and calibrate it as h_t^k's elasticity with respect to h_t. We base that elasticity on Mincer-equation estimates by Lee, Roys and Seshadri (2024), who include schooling of a respondent's parents, as well as one's own, as predictors of the respondent's wage. Assuming that (i) the respondent's schooling coefficient proxies for the impact of parental schooling on the parents' own human capital, and (ii) that parents' choice of e_t is orthogonal to their schooling, then η is identified by the estimated impact of parental schooling on the respondent's wage relative to the impact of their own. They estimate this ratio at about 0.21 (=.017/.082).

As in previous sections, we target a VSLY of $185,000 for the U.S. in 2006 (U.S. Environmental Protection Agency, 2020). To obtain a parent's $v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)$ and kid's $\tilde{v}(c_t^k)$ for the U.S. in 2006, we divide this VSLY by their respective consumptions. Given that we do not impose a fully parametric specification for the parent's utility function, we rely on welfare accounting (first order approximations) to get other countries' levels for $v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)$. Specifically, we chain welfare in the country with the second-highest level of per capita consumption in 2006, the Netherlands, to that with the highest, the United States, based on their differences in consumption, leisure, number of children, and children's human capital. In the same way, we proceed to link the third richest, Japan, to the Netherlands, and so forth. We

Table 6: CEW Growth: Baseline versus Extended

	Baseline			Extended					
	CEW growth	pop term	cons term	CEW growth	pop term	cons term	leisure term	quality term	quantity term
U.S.	5.4	3.9	1.5	4.7	3.1	1.5	0.1	0.3	−0.3
Neth.	4.5	2.5	2.1	3.7	1.7	2.1	0.0	0.4	−0.4
Japan	2.3	0.4	1.9	1.6	−0.2	1.9	0.0	0.2	−0.4
S. Korea	4.4	1.7	2.6	3.3	0.5	2.6	0.6	0.4	−0.8
Mexico	6.5	4.9	1.6	3.4	2.9	1.5	−0.3	0.1	−0.8
S. Africa	6.8	4.3	2.6	5.1	2.3	2.4	1.0	0.3	−1.0

Notes: Baseline results are based on the framework presented in Section 2, while the extended results are based on the framework presented in Section 5. CEW denotes average annual consumption-equivalent welfare growth, decomposed in subsequent columns to show contribution of the different terms. The period is 2003-2019 for the U.S., 1975-2006 for Netherlands, 1991-2016 for Japan, 1999-2019 for Korea, 2006-2019 for Mexico, and 2000-2010 for South Africa. Data sources are the Penn World Table 10.0 for population, consumption, and hours worked, time use surveys for fertility ("quality"), World Bank data for the number of kids per adult ("quantity").

then chain $v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)$ through time within countries to reflect the growth rates in each of their arguments.[14]

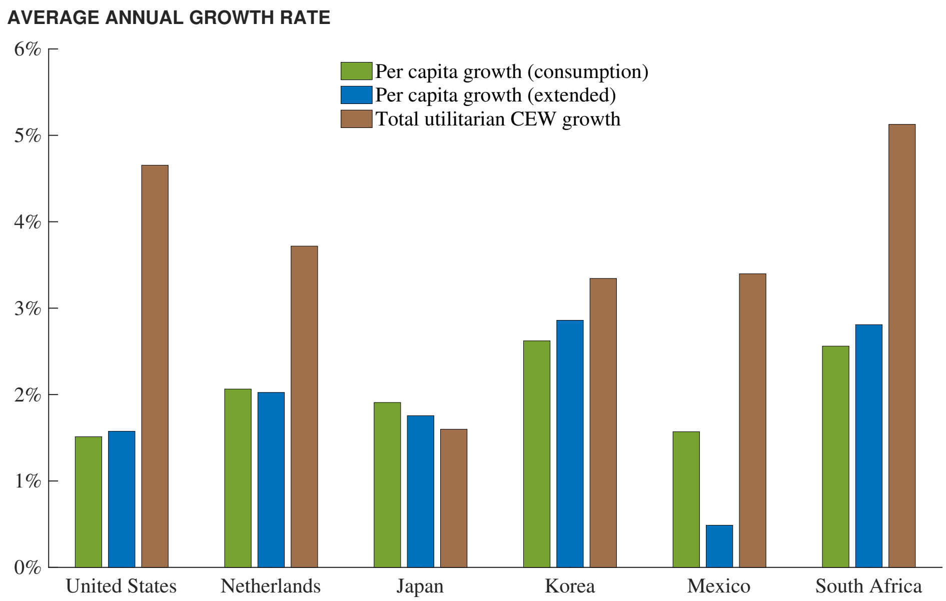
5.3 Results

Table 6 presents calculations of CEW growth based on the extended specification of individual preferences. We contrast these with the baseline calculations for the same six countries, where we adjust the period of the baseline calculation to match the years for which we have micro data. The table mostly shows modest net effects on total CEW growth from our added "per capita" terms (last three columns). The clear exception is Mexico, for which annual welfare growth is reduced from 6.5% to 3.3%. The culprits are falling leisure and little rise in quality of kids to offset their falling quantity.

The gaps between the baseline and extended CEW growth rates largely reflect smaller population terms in the latter case. As emphasized earlier, taking into account parental altru-

[14]In linking welfare through time within countries we use Tornqvist weights to value the factors. The Online Appendix has all the details.

Figure 14: Extended Growth Rates



Notes: For each country, the first bar depicts growth in consumption per capita, the second consumption-equivalent growth in per capita utility (based on the extended preference specification from Section 5) and the third is consumption-equivalent social welfare growth. (based on the extended preference specification as well). For data sources and years see the notes to Table 6.

ism leads to double counting kids' consumption, so that a smaller increase in consumption is equivalent to the value placed on additional people. But Table 6 shows that, quantitatively, this adjustment in the population term is usually modest, and population growth remains an important contributor to CEW growth.

For each country, Figure 14 illustrates the impact on CEW growth of extending per-capita welfare beyond consumption versus taking a total utilitarian view. In the per-capita approach, entertaining an extended measure of flow utility makes little difference. (Compare the first two bars for each country.) Any impact of trends in leisure and declining quantity of kids is mostly offset by rising kids' quality. The exception is Mexico, where leisure fell significantly over the period. In contrast, going from a per-capita to a total utilitarian approach makes a big difference (second to third bar). In particular, similar to Section 3's baseline results, under extended preferences Mexico moves up dramatically in terms of CEW growth relative to Japan due to their differing population growth.

6. Conclusion

While the growth literature has almost exclusively focused on per capita outcomes, we incorporate the value a country creates by adding more people. That is, we use a total utilitarian approach to value population growth in consumption-equivalent terms. Because of the diminishing marginal utility of consumption, each additional point of population growth is worth about five percentage points of per capita consumption growth in rich countries. Across a wider sample of 101 countries from 1960 to 2019, a percent of population growth is worth 2.7 percentage points of per capita consumption growth.

Countries with slow population growth — such as China, Japan, and Germany — plummet in our growth rankings. In contrast, middle-income countries exhibiting above-average population growth, such as Mexico, Brazil, and South Africa, move up. Lower income countries with rapid population growth, such as Ethiopia, do not move up as much because of the low standard of living used to weight their population growth.

We found our results to be robust to incorporating inequality, adjusting for migration, and incorporating parental utility from children and privately optimal fertility choices. Crediting migration entirely to source countries has modest net effects in most countries and does not alter our conclusions. Similarly, taking into account intergenerational utility has modest net effects because leisure exhibits little trend and the “quality” of kids is rising to offset the falling quantity of kids.

A. Derivation of CE welfare growth

A.1 Baseline: equation (2)

To begin, include λ_t as an adjustment to consumption so that $W_t = N_t \cdot u(\lambda_t c_t)$ and totally differentiate:

$$\begin{aligned} dW_t &= dN_t\, u(\cdot) + N_t u'(\cdot)\left[c_t d\lambda_t + \lambda_t dc_t\right] \\ \Rightarrow \frac{dW_t}{W_t} &= \frac{dN_t}{N_t} + \frac{u'(\lambda_t c_t)\lambda_t c_t}{u(\lambda_t c_t)}\left[\frac{d\lambda_t}{\lambda_t} + \frac{dc_t}{c_t}\right] \end{aligned}$$

To get the consumption-equivalent measure, we solve for the growth rate of λ_t that keeps us at the original level of welfare so that $dW_t = 0$ and we evaluate at the initial level of welfare with $\lambda = 1$:

$$\underbrace{g_{\lambda t} \equiv -\frac{d\lambda_t}{\lambda_t}}_{\text{CE welfare growth}} = \underbrace{\frac{u(c_t)}{u'(c_t)c_t}}_{\equiv v(c_t)} \cdot \frac{dN_t}{N_t} + \frac{dc_t}{c_t} \tag{14}$$

A.2 With Heterogeneity: equation (6)

We include λ_t as an adjustment to consumption of all individuals:

$$W(\lambda_t) = N_t \cdot \mathbb{E}_t u(\lambda_t \cdot c_{it})$$

Given log utility and the log-normal distribution of consumption:

$$W(\lambda_t) = N_t \cdot \left[\tilde{u} + \log \lambda_t + \log c_t - \frac{1}{2} \cdot \sigma_t^2\right]$$

Totally differentiating yields:

$$\frac{dW_t}{W_t} = \frac{dN_t}{N_t} + \frac{1}{\tilde{u} + \log \lambda_t + \log c_t - 1/2 \cdot \sigma_t^2}\left(\frac{d\lambda_t}{\lambda_t} + \frac{dc_t}{c_t} - \sigma_t^2 \cdot \frac{d\sigma_t}{\sigma_t}\right).$$

To get the consumption-equivalent measure, we solve for the growth rate of λ_t that keeps us at the original level of welfare so that $dW_t = 0$ and we evaluate at the initial level of welfare with $\lambda = 1$:

$$g_\lambda \; = \; \left(\tilde{u} + \log c_t - \frac{1}{2} \cdot \sigma_t^2 \right) \cdot \frac{dN_t}{N_t} \; + \; \frac{dc_t}{c_t} \; - \; \sigma_t^2 \cdot \frac{d\sigma_t}{\sigma_t}.$$

A.3 Beyond Consumption (general case): equation (9)

The social welfare function in the augmented framework of Section 5 is:

$$W(N_t^p,\, N_t^k,\, c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t) \; = \; N_t^p \cdot u(c_t^p,\, l_t,\, c_t^k,\, h_t^k,\, b_t) + N_t^k \cdot \widetilde{u}(c_t^k).$$

Define adjusted social welfare as:

$$W(\lambda_t) = \; N_t^p \cdot u\left(\lambda_t c_t^p, l_t, \lambda_t c_t^k, h_t^k, b_t\right) + N_t^k \cdot \widetilde{u}\left(\lambda_t c_t^k\right).$$

To avoid cumbersome notation, we will use the shorthand:

$$u_t = u(c_t^p, l_t, c_t^k, h_t^k, b_t).$$

Totally differentiating $W(\lambda_t)$ yields:

$$\begin{aligned} \frac{dW_t}{W_t} = \omega_t^p \cdot \Bigg[& \frac{dN_t^P}{N_t^P} + \frac{u_{c_t^p} \cdot c_t^p \cdot \lambda_t}{u_t} \cdot \left(\frac{d\lambda_t}{\lambda_t} + \frac{dc_t^p}{c_t^p} \right) + \frac{u_{l_t} \cdot l_t}{u_t} \cdot \frac{dl_t}{l_t} \\ & + \frac{u_{c_t^k} \cdot c_t^k \lambda_t}{u_t} \cdot \left(\frac{d\lambda_t}{\lambda_t} + \frac{dc_t^k}{c_t^k} \right) + \frac{u_{h_t^k} \cdot h_t^k}{u_t} \cdot \frac{dh_t^k}{h_t^k} + \frac{u_{b_t} b_t}{u_t} \cdot \frac{db_t}{b_t} \Bigg] \\ + \omega_t^k \cdot \Bigg[& \frac{dN_t^K}{N_t^K} + \frac{\tilde{u}'(\lambda_t \cdot c_t^k) \cdot \lambda_t \cdot c_t^k}{\tilde{u}(\lambda_t \cdot c_t^k)} \cdot \left(\frac{d\lambda_t}{\lambda_t} + \frac{dc_t^k}{c_t^k} \right) \Bigg]. \end{aligned}$$

where ω_t^p and ω_t^k are respectively:

$$\omega_t^p := \frac{N_t^p \cdot u_t}{N_t^P \cdot u_t \; + \; N_t^K \cdot \widetilde{u}(c_t^k)} \quad ; \quad \omega_t^k := \frac{N_t^K \cdot \widetilde{u}(c_t^k)}{N_t^P \cdot u_t \; + \; N_t^K \cdot \widetilde{u}(c_t^k)}.$$

To obtain CEW growth, we set $\frac{dW_t}{W_t} = 0$ and solve for $g_{\lambda_t} = -\frac{d\lambda_t}{\lambda_t}$ around $\lambda_t = 1$:

$$
\begin{aligned}
g_{\lambda_t} = \kappa_t \cdot \Bigg[\omega_t^p \cdot \Bigg(& \frac{dN_t^P}{N_t^P} + \frac{u_{c_t^p} \cdot c_t^p}{u_t} \cdot \frac{dc_t^p}{c_t^p} + \frac{u_{l_t} \cdot l_t}{u_t} \cdot \frac{dl_t}{l_t} \\
& + \frac{u_{c_t^k} \cdot c_t^k}{u_t} \cdot \frac{dc_t^k}{c_t^k} + \frac{u_{h_t^k} \cdot h_t^k}{u_t} \cdot \frac{dh_t^k}{h_t^k} + \frac{u_{b_t} b_t}{u_t} \cdot \frac{db_t}{b_t} \Bigg) \\
+ \omega_t^k \cdot \Bigg(& \frac{dN_t^K}{N_t^K} + \frac{\tilde{u}'(c_t^k) \cdot c_t^k}{\tilde{u}(c_t^k)} \cdot \frac{dc_t^k}{c_t^k} \Bigg) \Bigg],
\end{aligned}
$$

$$
\text{where} \quad \kappa_t := \left[\omega_t^p \cdot \left(\frac{u_{c_t^p} \cdot c_t^p}{u_t} + \frac{u_{c^k t} \cdot c_t^k}{u_t} \right) + \omega_t^k \cdot \frac{\tilde{u}'(c_t^k) \cdot c_t^k}{\tilde{u}(c_t^k)} \right]^{-1}.
$$

A.4 Beyond Consumption: equation (10)

The first order conditions from the parent's utility maximization problem are:

$$
\frac{u_l}{u_{c^p}} = wh \quad ; \quad \frac{u_{c^k}}{u_{c^p}} = b \quad ; \quad \frac{u_b}{u_{c^p}} = whe + c^k \quad ; \quad \frac{u_{h^k}}{u_{c^p}} = \frac{whbe}{\eta h^k}.
$$

The log specification in Assumptions 1 and 2 yield:

$$
v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) = u\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \quad \text{and} \quad \tilde{v}\left(c_t^k\right) = \tilde{u}\left(c_t^k\right).
$$

So that

$$
\kappa_t = \frac{N_t^P \cdot v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) + N_t^K \tilde{v}(c_t^k)}{(1 + \alpha \cdot b_t^\theta) \cdot N_t^P + N_t^K}.
$$

Plugging back in the expression for g_λ yields:

$$
\begin{aligned}
g_{\lambda_t} &= \pi_t^p \cdot v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \cdot \frac{dN_t^p}{N_t^p} + \pi_t^k \cdot \tilde{v}(c_t^k) \cdot \frac{dN_t^k}{N_t^k} \\
&+ \pi_t^p \cdot \frac{dc_t^p}{c_t^p} + (1 - \pi_t^p) \cdot \frac{dc_t^k}{c_t^k} \\
&+ \pi_t^p \cdot \left(\frac{u_{l_t}\, l_t}{u_{c_t^p}\, c_t^p} \cdot \frac{dl_t}{l_t} + \frac{u_{b_t}\, b_t}{u_{c_t^p}\, c_t^p} \cdot \frac{db_t}{b_t} + \frac{u_{h_t^k}\, h_t^k}{u_{c_t^p}\, c_t^p} \cdot \frac{dh_t^k}{h_t^k} \right),
\end{aligned}
$$

where

$$\pi_t^p = \frac{N_t^p}{(1+\alpha b_t^\theta)N_t^p + N_t^k} \quad ; \quad \pi_t^k = \frac{N_t^k}{(1+\alpha b_t^\theta)N_t^p + N_t^k} \quad ;$$

$$v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) = \frac{u\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right)}{u_{c^p}\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \cdot c_t^p} \quad ; \quad \tilde{v}(c_t^k) = \frac{\tilde{u}(c_t^k)}{\tilde{u}'(c_t^k) \cdot c_t^k}.$$

To implement this growth accounting, we use the optimality conditions and budget constraint from the parent's utility maximization problem to map the different weights to observables:

$$\begin{aligned} g_{\lambda_t} \;&= \pi_t^p \cdot v\left(c_t^p, l_t, c_t^k, h_t^k, b_t\right) \cdot \frac{dN_t^p}{N_t^p} \;+\; \pi_t^k \cdot \tilde{v}(c_t^k) \cdot \frac{dN_t^k}{N_t^k} \\ &+ \pi_t^p \cdot \frac{dc_t^p}{c_t^p} \;+\; (1-\pi_t^p) \cdot \frac{dc_t^k}{c_t^k} \\ &+ \pi_t^p \cdot (1+\alpha b_t^\theta) \cdot \frac{l_t}{l_{ct}} \cdot \frac{dl_t}{l_t} \\ &+ \pi_t^p \cdot \left(\alpha b_t^\theta \;+\; (1 \;+\; \alpha b_t^\theta) \cdot \frac{b_t \cdot e_t}{l_{ct}}\right) \cdot \frac{db_t}{b_t} \\ &+ \pi_t^p \cdot (1+\alpha b_t^\theta) \cdot \frac{b_t \cdot e_t}{l_{ct}} \cdot \frac{1}{\eta} \cdot \frac{dh_t^k}{h_t^k}. \end{aligned}$$

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