UTAH POPULATION & ENVIRONMENT COUNCIL

Utah's Fertility Decline: Richer Lives for All

A White Paper from the Utah Population and Environment Council (UPEC)

Principal author: Stephen C. Bannister, PhD

Fall 2020

(801) 508-4667 • PO Box 520402, Salt Lake City, UT, 84152 •
www.utahpopulation.org

UTAH POPULATION & ENVIRONMENT COUNCIL

Introduction

We all face many important choices as we live our lives and form relationships with others, and with society as a whole. Many factors influence population levels, of course, but this white paper will discuss one of the most personal and important choices we face that affects our population — how many children to bring into this world — and the implications of this choice for ourselves, and our state, nation, planet.

The coronavirus and our collective response to it has revealed much about the strengths and weaknesses of our society — and, we hope, caused many Americans to think more deeply about population growth and climate change. That the virus probably originated in bats or pangolins in the world's most populous nation was not a coincidence. Around the world, population growth and intensive agriculture have "uprooted the world's animals," writes Ed Yong in *The Atlantic*, "forcing them into new and narrower ranges that are on our own doorsteps. Humanity has squeezed the world's wildlife in a crushing grip — and viruses have come bursting out." (Yong 2020).

Here in Utah, the virus has provided us a glimpse into our various possible futures. For example, we enjoyed a stretch of remarkably good air quality in the spring of 2020. Of course, this environmental good resulted from the unprecedented harm of the economic shutdown, obviously not a repeatable or advisable route to good air. But the virus-induced pause did remind us that we can in fact have clean air if we change our energy and transportation habits — and, as this paper will show, if we flatten the curve of our population growth. The virus also led to overcrowded trails in the Salt Lake Valley, with some people even avoiding them because it was literally impossible to practice social distancing! Trail usage will flatten as life returns to normal, yet those crowded trails hint at what awaits us if Utah's population increases to 6 million in 2065, as predicted.

Yet many Americans actually pine for an acceleration of population growth. When most intellectuals, politicians, and everyday citizens currently consider population trends, whether for the United States as a whole or for Utah, they do not think much about the projected steady growth growing forward; rather, they often fret about the current decline in average fertility rates. They

thus assume that having children, and often many children, is almost always the right choice. This pro-population growth view comes from many different perspectives, from the religious and cultural to the economic. We focus on the economics of population. Today, a majority of economists across the political spectrum maintain that steady population growth (and hence lots of babies!) helps drive America's remarkable economic engine. Conservatives tend to argue that economic progress demands steady population growth (missing the fact that aggregate economic growth is not the same as per capita growth). Liberals tend to argue that, with an aging population, we need more kids and thus future workers to help pay the retirement bill of our seniors (exaggerating the problems of an aging population). Rarely does either side pause to reconsider the almost unspoken assumption that population growth is an unalloyed economic good.

We do just that in this white paper, critiquing the nearly unquestioned celebration of population growth that pervades our society. However, we do not do so from a desire that people should live in thatched huts without social media and streaming content! That is, we do not wish to roll back our living standards. In fact, we question never-ending population growth because it in fact erodes our living standards. To begin with, it unambiguously contributes to myriad environmental crises and exacerbates global warming; on average, every American born into the world today will produce an estimated 45,000 pounds of carbon dioxide. In addition, ceaseless population expansion harms our quality of life in myriad additional ways, from reducing wilderness to polluting the air in Salt Lake Valley to clogging the canyons on powder days. Many people are concerned about our environmental problems, but, because they assume that more people = more wealth and economic growth, they avoid connecting the dots between population growth and environmental harms. We offer a way out of this conundrum. The crucial point of this white paper is that we need not become any less rich per capita as we enjoy the ecological and aesthetic benefits of a smaller population.

The above point is a complicated one, and it is worth detangling for a moment more. We do not believe that reducing our population will make us poorer — even as traditionally defined. (Although we are sympathetic to efforts at redefining economic growth via a Genuine Progress Indicator, a Human Development Index, or even a Gross Happiness Index, these efforts

are outside the purview of this paper.) Humans are an ingenious species, and we prefer to keep busy, so of course population growth makes the whole economic pie bigger — the total Gross Domestic Product (GDP), to use the economists' term. However, what really matters to our wealth and happiness is not aggregate growth but per capita levels. And, in today's modern world, aggregate population growth does not necessarily increase per capita economic gains. Even more importantly, a gradually slowing rate of population growth, followed some time later by a stable or even a declining population, will improve the quality of life and enhance happiness in myriad ways.

This white paper thus proudly offers unconventional answers to questions surrounding population growth and the economy, answers that make sense for both individuals and the collective whole. We will show that population growth has little conclusive effect on per capita economic growth. Sometimes societies with high levels of population growth see high levels of per capita economic growth — think 1950s America. Sometimes countries with low levels of population growth also enjoy steady per capita gains — think today's Japan. There is simply too much influencing economic growth, from geopolitical conditions to trade policy to productivity growth, to untangle the exact effects of various population dynamics such as total size, growth rates, migration levels, and average age. Indeed, we find it somewhat amusing that so many economists generally emphasize twenty-first-century themes of technology and innovation but, when considering population, resort to a mercantilist, seventeenth-century notion that economic growth relies on the sheer body count!

As we will show, population growth has minimal influence on per capita income. We thus argue that further slowing the pace of population growth in Utah — and moving toward stabilization and then a decreasing population — will offer unambiguous benefits, from better air to more affordable housing to less crowded freeways and classrooms.

The focus here is on Utah, because we are a Utah-based organization concerned about the damage that our state's excessive population growth inflicts on our ecosystems and quality of life. However, we should not fall into the tempting trap of assuming that Utah's demographic culture represents a

great exception. It is true that Utah's unique history and culture have promoted especially vigorous population growth. Our state has traditionally had the highest birthrate in the United States, even if South Dakota may have recently knocked us off our perch! And we are growing faster than the U.S. as a whole. Our state's population is expected to increase from 3,193,000 today (2018) to 5,828,000 in 2065, an annual percentage increase of 1.3 percent (Gardner Policy Institute 2017a). The numbers for the U.S. are 326,767,000 and 412,055,000, an annual percentage increase of 0.5 percent (United Nations Population Division 2017). Nonetheless, Utah's population growth rate (and birthrate) are coming down in tandem with those for the nation as a whole; think of parallel sloping lines, with Utah's above the nation's. In addition, the widespread celebration of population growth, especially for its alleged economic benefits, looks little different on Temple Square than it does on Wall Street or in West Yellowstone, West Virginia, or Western Washington.

Although this paper primarily concerns the secular decline in Utah's Total Fertility Rate and makes the case that we should celebrate and encourage this decline, the current COVID-19 crisis does affect some of the key points we make.

Introducing our Model

To demonstrate that choosing fewer children is better — for individuals, society, and the planet — we have developed a new statistical approach. This new model reveals that we can discard the old prevailing notions about population and the economy. When our model considers historical living standards for each of us, what stands out is that they almost always (at least for the past three centuries!) grow irresistibly, even relentlessly. Even when the world endures a calamity that temporarily reverses growth, like the 2008 Great Financial Crisis, average living standards inevitably return to their prior path of ever-increasing growth. True, we face significant and growing problems of unequal income distribution, whether between the global north and south or within the United States. Yet, on average, the current inhabitants of the Earth are the richest people who have ever lived.

However, we all use a lot of stuff, especially fossil fuel. If we are to enjoy the

benefits of continued growth in living standards without further imperiling the planet, we in Utah — no differently than people across the world — should welcome the reduction in our fertility rate so that our total population eventually and gradually comes down. Reducing fertility will allow us to have our cake and eat it too: to enjoy the benefits of economic growth without enduring so many of its costs.

The next sections turn to the key statistical results from our model. First, we examine the likely path of future living standards, that is, per-person GDP (and consumption) here in Utah. Second, we examine the evolving dynamics of our state's population In the long run, population levels will be a major determinant of our quality of life in Utah. Those two factors are the major focus of this study; other important results covering energy consumption and carbon dioxide emissions, factors that will clearly impact our lives, are discussed in the appendices.

Living standards, past, present, and future

Like many economic studies, we define living standards as real per capita GDP. As mentioned, researchers have proposed various alternative indexes to overcome some of GDP's limitations; these alternative measures represent a very fruitful path of inquiry, but they do not have the long data history of GDP and are thus not usable in this paper. The graph below (Figure 1), which depicts real living standards in Utah between 1967 and 2017, takes a bit of explaining,

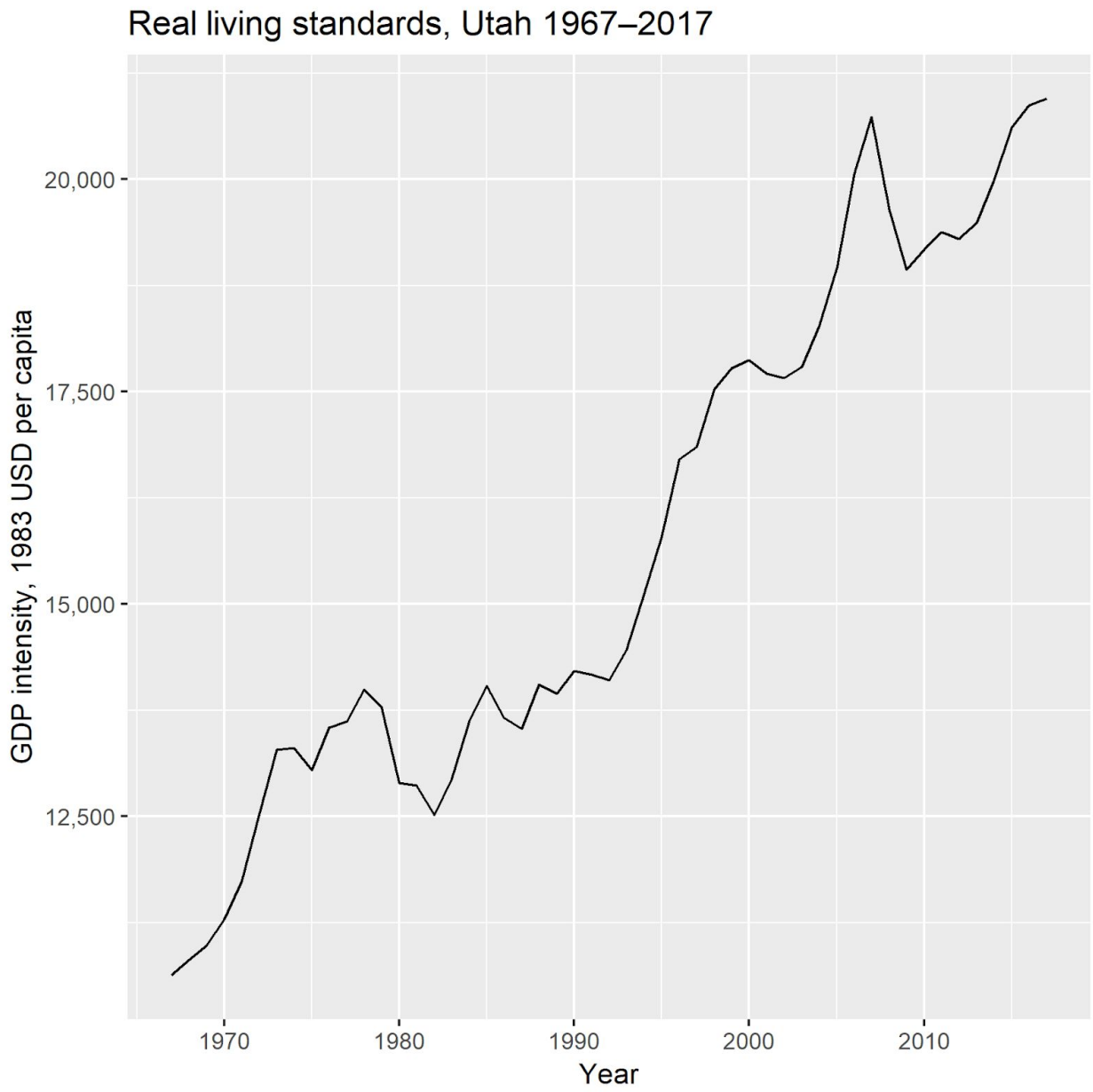

Figure 1

Figure 1 shows that we are unambiguously getting richer. With the important exceptions of a) rising inequality, which a growing number of us across the political spectrum find troubling and b) myriad environmental degradations, our rising wealth is a happy development. Moreover, continued wealth gains

seem nearly inevitable. Incomes have skyrocketed in most of the world in the wink of an eye since the Industrial Revolution. More recently, as the chart shows, our real living standards have increased steadily for the past half century, a trend interrupted only occasionally by recessions. Yes, many working-class Americans have seen stagnant wages since the 1970s (though this trend has been less pronounced in Utah). But this fact does not take away from the underlying, steady gains in per capita production and hence in consumption.

Let us note an important Utah anomaly. Because of its strong general upward trend, Figure 1 partially obscures the fact that Utah living standards suffer significantly during recessions, indeed significantly more than in the United States as a whole. Looking at this effect during the Great Recession of a decade ago, Utah's real per capita living standards decreased by 8.7 percent from the pre-recession peak of $20,731 in 2007 to the recession bottom of $18,937 in 2009. (Both figures here are indexed to 1983 dollars.) (U.S. Bureau of Economic Analysis 1997). This decline represented a large hit to real living standards. By comparison, living standards in the entire U.S. declined 5.2 percent from the fourth quarter 2007 pre-recession peak of $52,049 to the second quarter 2009 recession bottom of $49,318. (Both figures here are indexed to 2012 dollars.) (U.S. Bureau of Economic Analysis 2018). Utah's surprising, larger-than-normal decrease in living standards during the recession prompts questions about how we might make the state's economic mix more resilient to inevitable future recessions. Prior recessions reveal a similarly worse performance for Utah, so its experience from 2007–2009 was not an isolated event.

The persistent long-term increasing trend in GDP per person, or living standards, is interrupted only during recessions. We thus expect a substantial decrease in living standards during 2020's COVID-19–induced recession. During the Great Recession, Utah's living standards decreased by about five percent, so we anticipate a substantial decrease during the current crisis.

Now that we have examined Utah's actual living standards, we turn to the important question — what do future living standards look like? To answer this, we provide a forecast using time-series forecast methods as described in

the methodology appendix. This is a model-based forecast, although our forecast considers a long history of the relevant data and uses the best available forecasting method to produce the results. Living standards are calculated by dividing Utah GDP by Utah population.

The news on future living standards for Utahns is good.

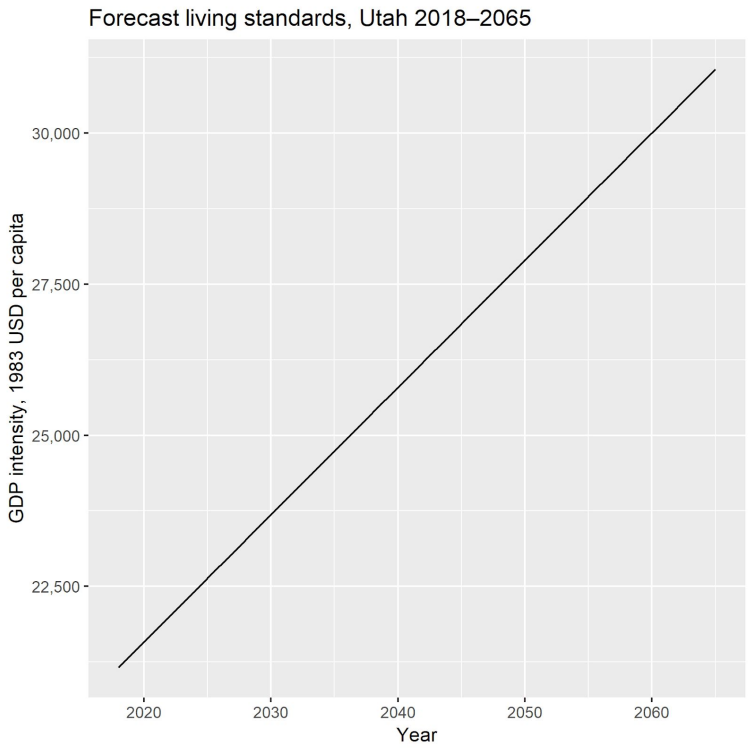

Figure 2

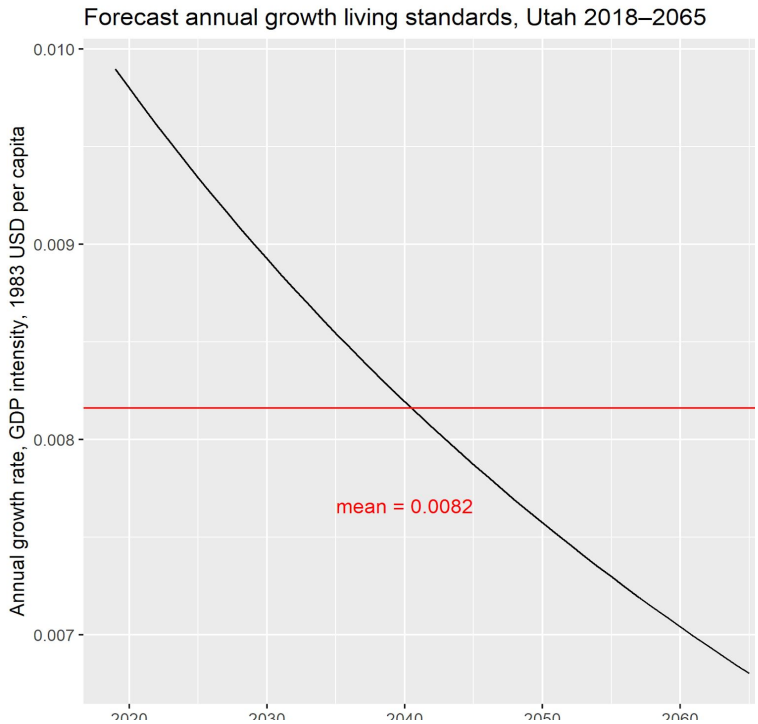

Figure 3

The statistically best forecast that the historical data can produce, shown in Figure 2, is a straight line, rising from about $20,000 in 1983 dollars in 2017 to about $33,000 in 1983 dollars in 2065. In 2017 (or "current") dollars, this ending number would be about $84,000.[1] More importantly, our model, as seen in Figure 3, predicts about a 1 percent annual increase in living standards; this forecast is a bit below the historical average of 1.4 percent annual growth, but this modest difference largely reflects the large hit to living standards from the Great Recession of 2007–2009. So our estimated growth rate is conservative, and the gains may be greater, though the effects of the 2020 recession will lower the growth rate.

Our model indicates that living standards will unmistakably increase, regardless of the rate of population growth. Prior to about 1880, the world was very Malthusian (Thomas Robert Malthus 1826). This means that every

[1] We multiply the 2017 annual price index of 254.7 by the 2065 estimate of $33,000 in 1983 dollars.

time living standards rose, more babies were born (that is, women's total fertility rate — TFR — increased). Before the Industrial Revolution began in England in the eighteenth century, this Malthusian relationship meant that living standards could increase for only brief historical periods before the added output was consumed by new babies and the world returned to lower — essentially subsistence — living standards.

The productivity revolution wrought by the Industrial Revolution began to remove supply (output) constraints in the eighteenth century so that even as TFR and babies increased, living standards also still increased. Then, around 1880, another profound change took place. The Malthusian "sign" flipped, and increased living standards led to *fewer* babies (lower TFR). This "demographic transition," really a demographic revolution, gradually spread around the world and now works its magic in almost every country, including those in sub-Saharan Africa. When the demographic transition happens, total output still keeps increasing, and, now shared by relatively fewer people than before the transition, makes everyone's income and wealth higher, at least on average.

What lessons should we Utahns take from this? First, living standards will likely increase even as Utah's population growth rates continue their modest but steady fall because total output, driven by productivity increases, continues to rise. As a result, second, we need not worry about the economic effects of lower growth. Indeed, we should embrace this happy development! Lower population growth rates, and lower total population levels, are both worthy goals for Utah because, all else equal, the combination of these two (the first is already taking place!) would bring so many quality-of-life and environmental benefits. As a result, third, we should embrace policies that nudge us further along the path to lower fertility. We passionately support the voluntary right of women and couples to choose their family size, but we do hope that Utahns will increasingly consider having just two children, or even stopping at one.

Our optimistic approach to the economics of decreasing population growth may seem counterintuitive. After all, population growth and economic growth have often moved together the past few hundred years, since the Industrial Revolution. How could they not have, given that, since 1800, we have

progressed from incomes of $3 a day to $100 a day in the wealthy world, while the total global population has increased from 1 to nearly 7.5 billion!? However, modern economic growth, especially in wealthy, knowledge-based economies, is driven by innovation and productivity increases — not by the sheer body count. Yes, if we had ten billion people in Utah, of course we would make a lot more stuff in the aggregate than we do with three million. But what matters above all is not the total size of the economy but per capita growth and living standards — that is, how well, or poorly, each of us lives.

And the relationship between population growth and per capita economic growth is no longer very consistent. To be more specific, let's look at Japan, the largest case (by GDP) of a nation with a declining population. As seen in the figure below, though total population levels in Japan are falling, living standards measured as GDP per capita continue to grow. By way of a direct comparison with our nation, since the economic collapse of 2007, Japan's economy has grown 1.4 percent a year on a per capita basis. The American economy has grown .8 percent annually on a per capita basis (Baker 2019). Put another way, Japan's shrinking population is getting richer — and even richer than the U.S.'s. The good news is that we thus need not fear the nearly inevitable spread of Japan's phenomenon of wealth gains combined with a shrinking population to the rest of the developed world.

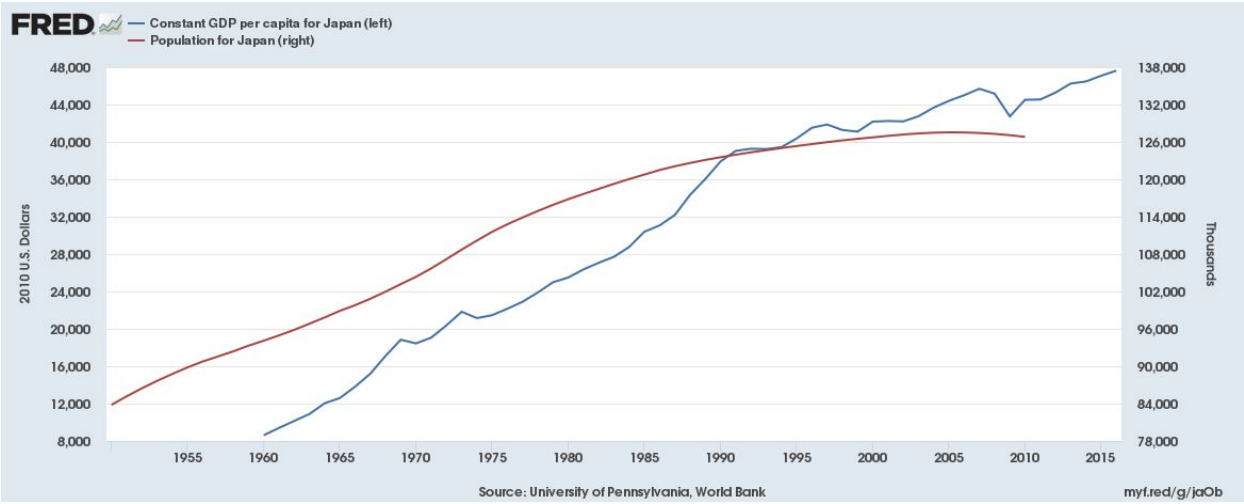

Figure 4

Japan offers the most clear cut example of this phenomenon because its population has actually declined; many other advanced nations have not yet seen absolute population declines, but their demographic and per-capita growth charts point in the same direction. The larger context is that per capita economic growth no longer consistently correlates with population growth, and certainly is no longer dependent upon it, if it ever was! We all can become richer as traditionally defined even while embracing a smaller population.

We have established that population and per capita economic growth are tenuously linked. At the very least, declining population levels need not depress economic gains. It is also worth noting that economic growth theory has long suggested that the causal relationship may run the other way — that declining population growth may in fact help Utah enjoy higher average living standards than it would otherwise. The notion that slowing population growth provides a spur to economic development is a very old idea that stretches back to the "classical economists" — that is, Adam Smith, John Stuart Mill, and many other of the market-oriented founders of modern economics (Hoff 2012, chap. 1). This idea enjoyed particular currency during the middle decades of the twentieth century, when economists focused on the challenge that rapidly rising populations (and poverty) posed in what was then called the "Developing World." However, even many economists examining the developed nations reached the conclusion that reducing birth rates and slowing population growth in the wealthy world would enhance per capita growth, in particular because a flattening population would create incentives for capitalist economics to ensure that each person consumes an ever-increasing amount. During the 1970s and 1980s, these pro-market-meets-pro–population stabilization ideas went into abeyance, but they rose again in the 1990s, when many economists observed that the "Asian Tiger" nations enjoyed tremendous economic gains once their birthrates came down.

The argument that a lower population encourages economic growth may offer little comfort to some environmentalists. Indeed, some readers of this study may advocate for zero-growth or even de-growth in living standards as a desirable policy response to climate change. But, while it is absolutely true that reducing economic output would reduce emissions and slow climate

change, both data and theory indicate that slowing the economic-growth machine is very unlikely, either in Utah or in the world as a whole. That is the message embedded in Figure 2 for Utah — and the graph for the entire world is very similar. The Utah data (and Figure 3) support a very small dip in the rate of growth in living standards through the forecast period. Note that this decrease — a decrease in the rate of *gains* — is less than one-tenth of one percent per year, and even it may reflect a "hangover" in the data from the 2007–2009 Great Financial Crisis and recession rather than any real changing trend in consumption behavior.

Although the structure of the future economy is outside the scope of this paper, certainly many of us would prefer that these inevitable economic gains coincide with changes in our energy regimes and other environmental practices that move away from our most destructive habits. Cross-country ski passes, massages, and burning coal all count toward GDP; but we would prefer more of the first two and less of the third! Regardless of how technology and consumption patterns develop, however, a smaller population requires less coal, all else equal. So reducing the population is a moderate step we can take toward improving our environmental footprint without harming GDP per capita.

This section has shown that average living standards will likely grow with or without population growth. Now that we have examined living standards, we turn specifically to the forecast and actual population levels for Utah.

Population past, present, and future

For this study, we take the results of the population report produced by the University of Utah's Gardner Policy Institute in 2017 (Gardner Policy Institute 2017a).

Figure 5 below displays this report's forecast for future population (Gardner Policy Institute 2017a). For context, Figure 6 depicts Utah's actual population level from 1940–2017 (U.S. Bureau of the Census 1900).

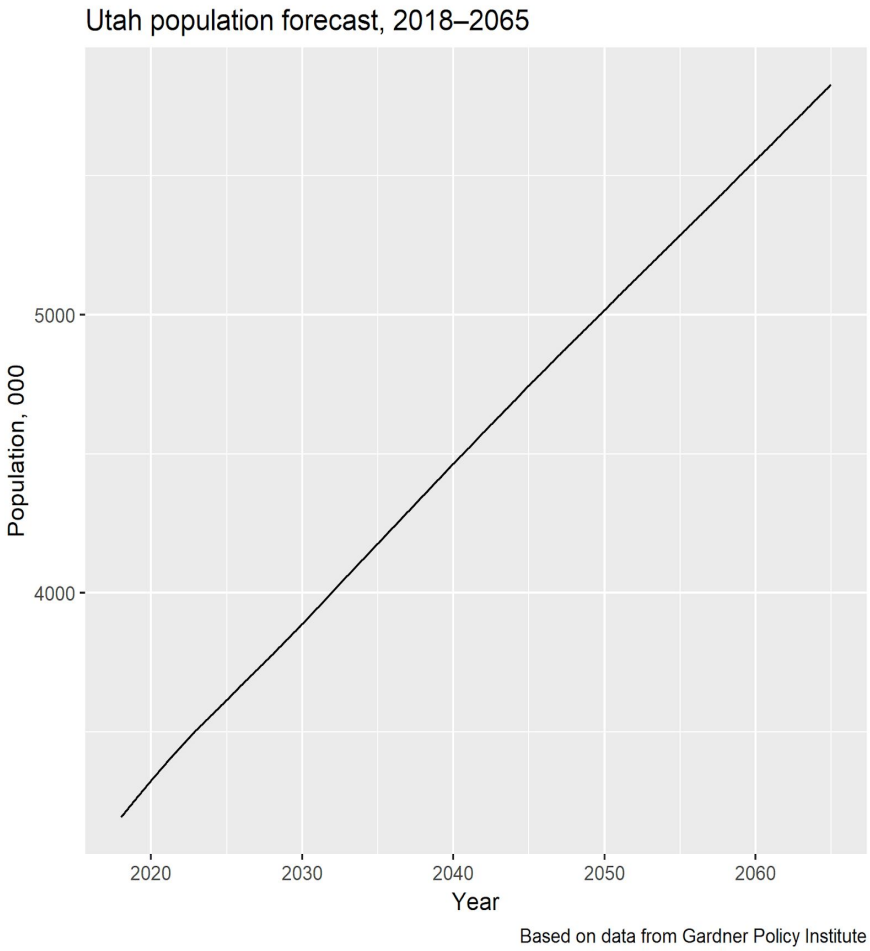
Utah population forecast, 2018–2065
Population, 000
5000
4000
2020
2030
2040
2050
2060
Year
Based on data from Gardner Policy Institute

Figure 5

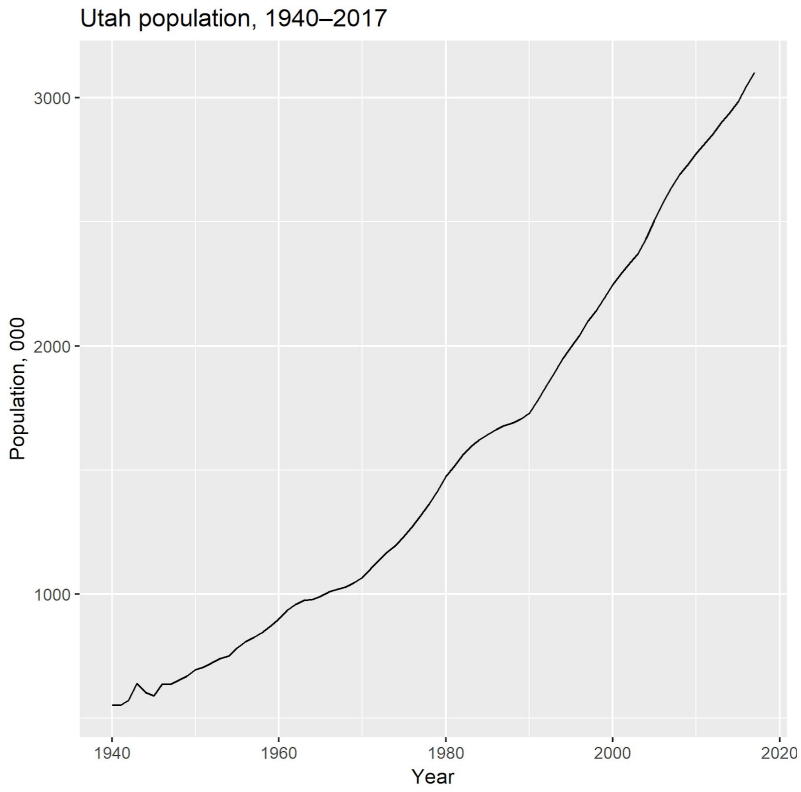

Figure 6

Figure 5 forecasts an almost linear increase in Utah's population, nearly doubling in half a century from about three million in 2017 to almost six million in 2065. Net migration (which encompasses both immigration from other nations and migration from other states) will account for about 30 percent of this projected growth (Gardner Policy Institute 2017b, p.1).

The expected doubling of Utah's population masks the fact that the state's population growth rate, measured as the annual percentage change in population levels, will continue to decrease (albeit from a very high starting point). As Figure 6 above shows, from 1940 through 2017, the annual percentage growth of the population in Utah was about 2.2 percent. The Gardner Institute forecasts that this annual growth rate will decrease to about 1.3 percent by 2065 (Gardner Policy Institute 2017a, p.1).

Although the difference between the current growth rate (2.2 percent in 2017) and the forecast growth rate at the end of this curve (1.3 percent in 2065) seems small at first glance, such different rates, over the long-term, leave vastly different demographic and ecological regimes in their wake. The lower the population growth rate, the better our lives will be, so we should welcome the existing fertility trends and take actions to reinforce them.

How does the COVID-19 crisis affect the TFR projection? Because this health crisis has also caused an ongoing economic crisis, seen most vividly in the large increase in unemployment, we expect that the TFR will further decline during the current unemployment crisis. A multi-country study of the Great Recession (Comolli 2017) shows that the Great Recession caused a three percent decrease in TFR, which equates to a decrease of 0.05 births per woman. Given that the employment effects in the current COVID-19 crisis exceed those in the Great Recession, we expect a larger decrease in TFR.

Indeed, nudging us toward lower fertility in Utah is UPEC's primary mission. In Utah, as well as in the world as a whole, it turns out that lowering population growth is usually about accelerating existing trends — pushing water downhill, so to speak. As living standards rise (and the world becomes ever more urban), the total fertility rate declines for a whole complex of reasons. In the past few decades, moreover, population experts have emphasized that very real increases in female empowerment (Project Drawdown 2017) and education have further spurred demographic transitions — outcomes that we obviously value over and above their effect of lowering total global fertility. The demographic transition is really a revolution!

Although many demographic and social trends across the globe are positive, this rosy trajectory comes with one major caveat — while we wait for the world's population to crest and slowly decline sometime late in this century, we may suffer greatly due to the planet's inexorable warming. Humans will find a way to survive on planet Earth with upwards of 9–11 billion without burning up. But why would we want to live on the "Hothouse Earth" that seems on the way? Do we really want to maintain the status quo in a world that will lose 60 percent of its species in the coming decade alone, as some scientists predict? (Kolbert 2014). It is crucial that, during the next few decades, we mitigate our bad environmental trends as we wait for the good

trends in fertility to reduce the pressure on the environment. However, a radical movement to roll back economic growth around the world is extremely unlikely to materialize, and the success of such a movement is even more unlikely. (Moreover, such "success" might produce several deleterious unintended consequences such as reversing the present trend of lessening inequality among nations.) As mentioned, however, we can and should change our mix of goods and services while still producing economic growth. And we can and should make great environmental improvements by altering our energy regimes. These goals represent the great moral, geopolitical, and economic challenges of our time; in comparison, reducing fertility is one of the least radical and most effective tools we have with which to combat environmental crises.

Discussion

We hope that this paper has demonstrated that slowing population growth, and even decreasing the total in population, will not harm Utahns. Indeed, UPEC welcomes the continued downward trend in fertility in Utah as a positive good. We do not believe in the widely held fallacy that we need large families and ever-more people and companies relocating to the state to make us richer. We also reject the notion that the cost of continued economic progress is agreeing to suffer through inversions (for example). We can slow the growth of economic pie, or even shrink it, while continuing to enjoy gains in individual living standards.

The core message of this paper is that Utahns will likely be better off even as population growth declines: better off in traditional economic terms as well as quality of life ones. This message is unambiguous because the accumulated data portend continued great momentum in the increase in living standards, interrupted only by recession. Of course, the fact that we will be richer as a whole for the foreseeable future says nothing about the distribution of income and consumption; those are largely in the realm of the political system. Utah currently enjoys the most equal distribution of income of any state, but we are becoming less equal.

We are aware of some of the potential criticisms of our findings. Many people sympathetic to the environmental critique of population growth nonetheless

fret about the supposed economic dangers of the widespread "aging" of the population in wealthy nations. According to the line of thinking, an aging population busts the budget (especially via social security spending) and also drags down economic growth (especially because the old tend to consume less than those in their prime earning years). Both of these concerns are overstated at best, and perhaps simply wrong. The U.S. has a looming entitlement problem, it is true, but the lack of political will to make modest changes to the system is a much greater problem than the demography itself. And, of course, the population pyramid will look very different once Baby Boomers (the "pig in the python") are a smaller percentage of the population. Meanwhile, an aging population often *positively* correlates with per capita economic growth; it boosts total savings, increases the average skill level per worker, and triggers technological innovation (for a review of these arguments, refer to Hoff 2012, chap. 8).

Next, it is common to hear people argue that population problems will simply "take care of themselves." Indeed, a few outliers are now publishing books with titles like *The Empty Planet* (Bricker and Ibbitson 2019). Yes, it is true that global population growth will eventually slow and then decline (though almost certainly not as dramatically as these outliers predict). But regardless of whether global population peaks at 9, 10, or 11 or billion, the larger problem is that we may fry the living inhabitants before we reach this peak. "The planet groans every time it registers another birth," to steal a line from Paul Simon.

Reacting to our planet's demographic-environmental trends, some very smart, socially concerned people argue that we must radically roll-back consumption levels. We absolutely admire efforts to consume less. However, people like to consume, and most economic systems, in rich and poor nations alike, are organized to encourage them to do so. The world can change in a heartbeat once in a while, it is true, but we do not foresee capitalism losing its grip any time soon as the dominant system through which most societies on Earth primarily organize the allocation of resources. Again, it is very likely that Utahns, like most of the world population, will increase their living standards. We are hopeful that, as environmental crises get even more acute, more companies and individuals will seek meaningful changes that allow us to capture more of the benefits of rising living standards without the ecological harms. This is one of the most important tasks of the twenty-first century.

While we grapple with such an important task on many fronts, we at UPEC actually believe that slowing population is one of the easiest and most effective steps that we — as a society, as Utahns, and as individuals — can take to improve our lives and to repair the planet.

So what can we all do? Most obviously, each of us should think about whether to stop at two kids, and maybe even consider having just one. And we should stop sending so many societal signals that stigmatize those who choose to have no children at all. We should make birth control much cheaper and much more accessible than they currently are around the nation and the world. We should continue to promote women's rights and invest in women's education everywhere.

To avoid continued ecological damage as per capita living standards continue to rise, it is imperative that we fund basic research to implement new energy sources with dramatically lower costs than anything currently available, whether clean or dirty. Given a sufficient price differential, the new clean cheap sources will drive out the old dirty ones. This paper has shown that, as we continue to work on decarbonizing our energy sources, we should embrace the downward trends in fertility across the world and in Utah, and work to accelerate them, resting assured that our wealth will expand along with our quality of life.

Literature

The modeling approach in this paper is significantly different than those used in most climate-oriented research; it is therefore not subject to some of the criticisms directed toward those approaches. For an example of these criticisms, see Robert P. Murphy) (2012) on William Nordhaus, a dominant climate-modeling economist and Nobel Prize winner.

Our paper uses a modeling philosophy originating with Paul Ehrlich and John Holdren (Ehrlich and Holdren 1971). This model, called IPAT (for Intensity, Population, Affluence, Technology), was extended by Yoichi Kaya to focus on population, energy, and carbon dioxide emissions (Kaya and Yokobori 1998). Michael Raupach et al. used the "Kaya Identity" developed in that paper in an extensive regional assay of carbon dioxide (Raupach et al. 2007). The United

Nations–sponsored Intergovernmental Panel on Climate Change (IPCC) used the Kaya model to assess a group of IPCC-sponsored climate models (Nakicenovic et al. 2000).

More recently, we have used the Kaya model to forecast living standards and carbon dioxide emissions (Bannister 2011). Adrian Raftery et al. started using Kaya in a model of UN population estimates (Raftery et al. 2017). Enno Schröder and Servaas Storm (Enno Schröder and Servaas Storm 2018) transformed Kaya to estimate how negative the global growth rate would have to go in order to attain sustainable climate conditions. That news is not good—global living standards would have to decline by -0.62 percent annually.

The innovation in this report is applying the Kaya forecasting approach to the state of Utah data to understand the projected growth in living standards, and the implications of that growth for our citizens.

Data

Table 1, shown below, lists the data-source citations used in this study; interested parties may download the data and reproduce our results.

Table 1. Data and sources

Data	Source/citation
Utah Population forecast	(Gardner Policy Institute 2017a)
Utah population historic actual	(U.S. Bureau of the Census 1900)
Utah gross domestic product, 1963–1997 (SIC code) [2]	(Bureau of Economic Analysis 2010)
Utah gross domestic product, 1997–2017 (NAICS code)	(Bureau of Economic Analysis 2018)

[2] Because of the change in industry reporting categories in 1997, changing from SIC classification to NAICS classification, we had to splice two series together for the desired time series. Contact the author for details,if desired.

Utah energy consumption	(U.S. Energy Information Administration—energy consumption 2018)
Utah carbon dioxide emissions	(U.S. Energy Information Administration—emissions 2018)
Utah consumer price index (CPI)[3]	(Bureau of Labor Statistics data 2018)

Methodology

Briefly, the modeling methodology in this paper uses the three Kaya Identity "intensities": 1) GDP intensity of population — real per-capita living standards; 2) energy intensity of GDP — how efficiently we use energy from all primary energy sources[4]; and 3) carbon intensity of energy — on average, how much carbon is embedded in our primary energy sources are. All are calculated using actual Utah historical data. See Table 1 for the Kaya model symbols. Their use is detailed in other sections of this paper.

Table 2. Kaya methodology

Kaya model symbol	Variable Type	Source
P	Population level	(Gardner Policy Institute 2017a)
G	GDP level	(U.S. Bureau of Economic Analysis 1997)
E	Energy consumption level	(U.S. Energy Information

[3] Used to convert nominal GDP data to real GDP, using 1983 as the basis, or the year in which the price index is 100.0.
[4] Primary energy sources are the original source of energy: carbon, hydro, wind, solar, nuclear and so forth. Electricity is a secondary (manufactured) energy source.

		Administration—energy consumption 2018)
F	Carbon dioxide (CO_2) flow	(U.S. Energy Information Administration—emissions 2018)
g (living standards)	GDP intensity ratio G/P	author's calculation
e	Energy intensity ratio E/G	author's calculation
f	CO_2 intensity ratio F/E	author's calculation

A statistical model is "fitted" to each intensity series. The methodology with the best fit in all cases was state-space modeling. State-space is a relatively recently formalized method for modeling time series; however, the methodology has been used extensively in financial series modeling under the category of exponential smoothing for decades. It has some very appealing properties, including that it often outperforms more common methods such as ARIMA in forecast accuracy. We fit a state-space model each intensity series, producing a forecast for each series through the year 2065.

We then multiplied these forecasts through with the population forecast to yield forecasts of the variable levels of interest, GDP, energy consumption, and CO_2 flux. The algebra is very simple: $F = P \cdot g \cdot e \cdot f$ is the complete model, yielding F, the carbon dioxide flux, or flow per period. The intermediate results used in this paper are likewise very simple. For example, for living standards, we simply take the forecast for *g*. For details on model methodology, see Hyndman and Khandakar 2008.

Appendix: The rest of the model

Energy intensity: The Hidden Fundamental Driver of our System

In our model, living standards, essentially our material well-being, operate on the rest of our global system through the amount of energy the system consumes. We measure energy consumption as the amount of energy inputs required per unit of output, with output usually measured as GDP. The trend in Utah's energy efficiency should translate to less carbon pollution from production, and, when combined with slowing population growth, will lead to reduced pollution even with increased living standards.

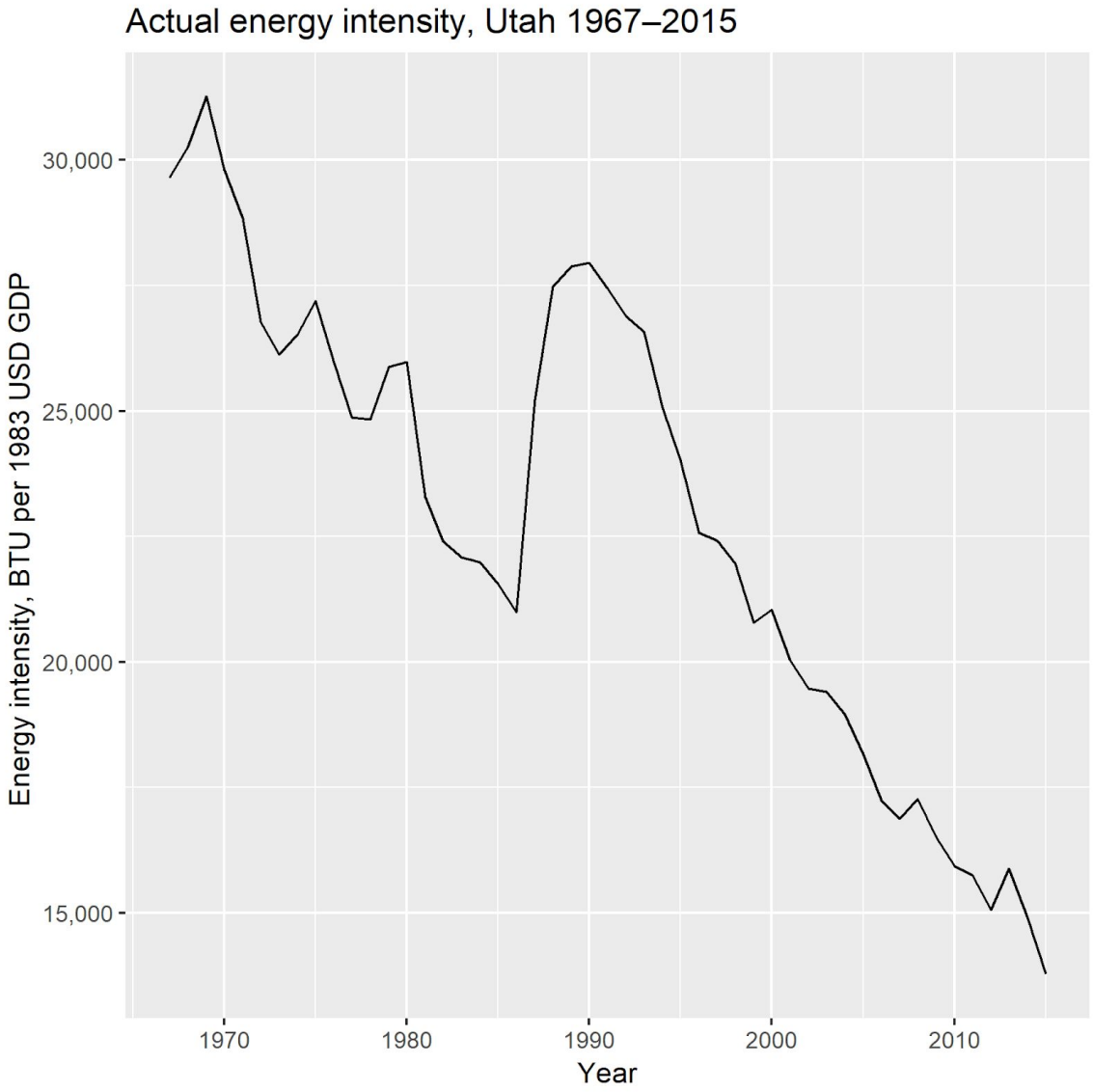

Figure 7

Figure 7 shows the actual real energy intensity in Utah since 1967. The units are British Thermal Units (BTU) per dollar of GDP, using 1983 as the base year. A lower number means better energy efficiency; we see that Utah's energy efficiency has been improving, especially since about 2005.

This improvement is very welcome. Energy efficiency improvements are often cited as being the cheapest way to mitigate climate change; as population and living standards increase, total energy consumption increases, but at a decreasing rate. Energy input is fundamental to any economic activity; without energy inputs, there would be no economic outputs. We will not go into the thermodynamics driving this relationship, but this link is one of the strongest between science and economics.

Thus, efficiency improvements mean that we will get more economic output — higher living standards — per unit of energy input. The reasons behind Utah's energy efficiency improvements, which mirror improvements in the overall U.S. picture, are varied. Important contributors include efforts to conserve by individuals and companies, the very high price of oil in 2006, the move during the 1980s to import more manufactured goods (this removes the carbon pollution from our state and "exports" it to developing nations such as China), and pro-environmental policy initiatives such as Energy Star.

The energy consumption data includes all primary sources of energy, both carbon-based and renewable. Electricity is a secondary source as it requires a primary source to produce it. The way we discriminate between clean and dirty energy sources is through a measure called carbon intensity. We now turn to that discussion.

Carbon Intensity: How Dirty are our Energy Sources?

The answer to this question is still very dirty, but increasingly less so.

Consider the following graph:

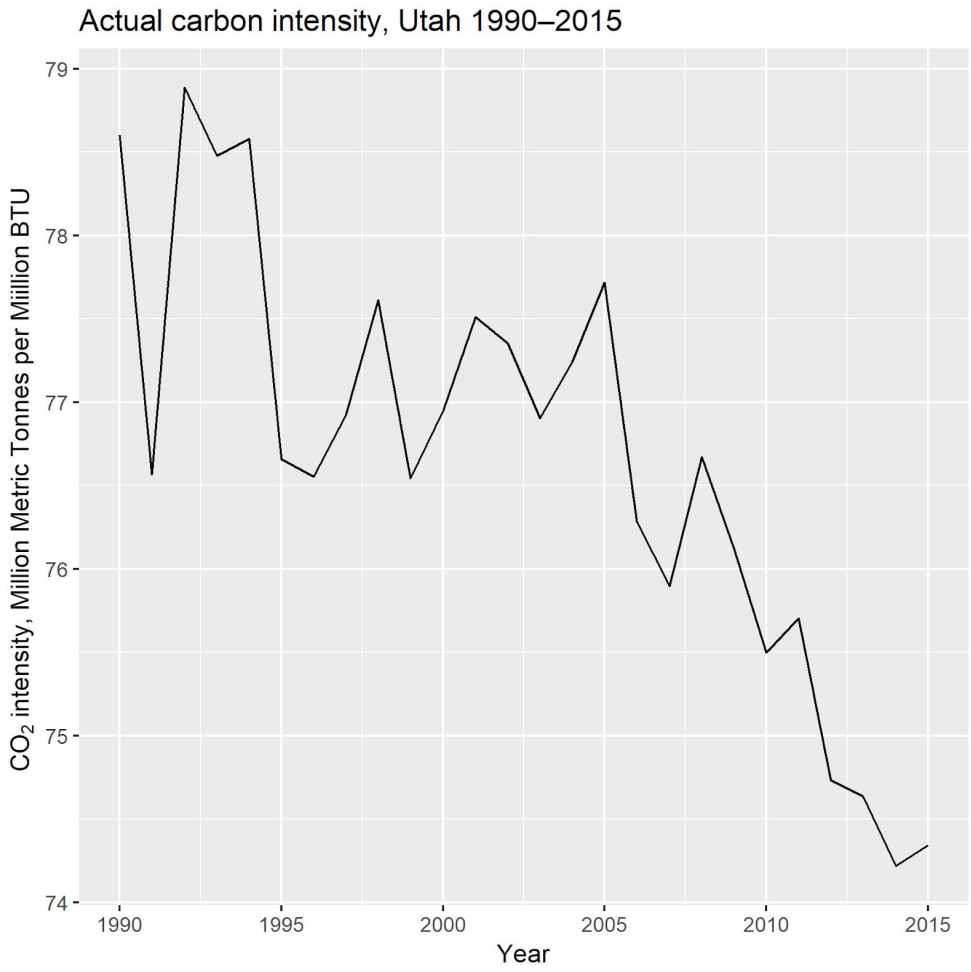

Figure 8

Figure 8 indicates how much carbon dioxide each unit of our energy produces. The units are very large: we use million metric tonnes of carbon dioxide output, and trillion British Thermal Units of energy input. This graph in other words illustrates the most critical fact, and parameter, of our entire economic/energy system: for completely clean energy, at the theoretical limit, this graph would not exist. The carbon dioxide emissions per unit of energy input would be zero. To "fix" our global warming problem caused by

carbon dioxide emissions, we would like completely carbon-free energy sources.

We note that Utah's energy sources have been getting cleaner since 2005. We have not seen that large of a percentage change, but we are moving in the right direction. Because this calculation includes all energy sources including renewables, and all carbon dioxide emissions across all primary energy sources, including renewables, it is a "fair" measure of the carbon "dirtiness" of our energy sources.

The improvement is welcome, but not enough to make a difference compared to a zero-carbon-intensity system. We should do everything possible to clean and decarbonize our energy sources, and we have a lot more work to do on the local, national, and global scale because all those scales affect our lives.

Bibliography

Baker, Dean. 2019. "The Old Japan Disaster Horror Story | Beat the Press | CEPR." June 2019. http://cepr.net/blogs/beat-the-press/the-old-japan-disaster-horror-story.

Bannister, Stephen. 2011. "The Limits to Degrowth: Challenges for Heterodoxy 20th Anniversary Conference of the Association for Heterodox Economics De Montfort University, Leicester, UK, 5–7th July 2018."

Bricker, Darrell, and John Ibbitson. 2019. *Empty Planet: The Shock of Global Population Decline*. New York: Crown/Archetype.

Bureau of Economic Analysis. 2010. "SAGDP2S Gross Domestic Product (GDP) by State, 1963–1997, SIC Codes." 2010. https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=1&isuri=1.

———. 2018. "SAGDP2S Gross Domestic Product (GDP) by State, 1997–2017, NAICS Codes." https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=1&isuri=1.

Bureau of Labor Statistics data. 2018. "CPI-All Urban Consumers (Current Series)."

Comolli, Chiara Ludovica. 2017. "The Fertility Response to the Great Recession in Europe and the United States: Structural Economic Conditions and Perceived Economic Uncertainty." *Demographic Research* 36: 1549–1600.

Ehrlich, Paul R., and John P. Holdren. 1971. "Impact of Population Growth." *Science* 171 (3977): 1212–17.

Enno Schröder, and Servaas Storm. 2018. "Why 'Green Growth' Is an Illusion." Institute for New Economic Thinking. https://www.ineteconomics.org/perspectives/blog/why-green-growth-is-an-illusion.

Gardner Policy Institute. 2017a. "Population 2010–2065 Gardner Projections Utah." http://gardner.utah.edu/wp-content/uploads/Gardner-Policy-Institute-State-and-County-Projections-Data-2017.xlsx.

———. 2017b. "Utah's Long-Term Demographic and Economic Projections Summary." July 2017. http://gardner.utah.edu/wp-content/uploads/Projections-Brief-Final.pdf.

Hoff, Derek S. 2012. *The State and the Stork: The Population Debate and Policy Making in US History*. Chicago: University of Chicago Press.

Hyndman, Rob J., and Yeasmin Khandakar. 2008. "Automatic Time Series Forecasting: The Forecast Package for R." *Journal of Statistical Software* 26 (3): 1–22.

Kaya, Yoichi, and Keiichi Yokobori, eds. 1998. *Environment, Energy, and Economy: Strategies for Sustainable*. Tokyo ; New York: United Nations University.

Kolbert, Elizabeth. 2014. *The Sixth Extinction : An Unnatural History*. New York: Henry Holt and Company.

Nakicenovic, Nebojsa, Joseph Alcamo, A. Grubler, K. Riahi, R. A. Roehrl, H. H. Rogner, and N. Victor. 2000. *Special Report on Emissions Scenarios (SRES), A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Raftery, Adrian E., Alec Zimmer, Dargan M. W. Frierson, Richard Startz, and Peiran Liu. 2017. "Less than 2 °C Warming by 2100 Unlikely." *Nature Climate Change* 7 (9): 637–43. https://doi.org/10.1038/nclimate3352.

Raupach, Michael R., Gregg Marland, Philippe Ciais, Corinne Le Quéré, Josep G. Canadell, Gernot Klepper, and Christopher B. Field. 2007. "Global and Regional Drivers of Accelerating CO2 Emissions." *Proceedings of the National Academy of Sciences* 104 (24): 10288–93. https://doi.org/10.1073/pnas.0700609104.

Thomas Robert Malthus. 1826. *An Essay on the Principle of Population*. https://en.wikipedia.org/w/index.php?title=An_Essay_on_the_Principle_of_Population&oldid=897665911.

United Nations Population Division. 2017. "World Population Prospects: The 2017 Revision." Department of Economic and Social Affairs.

U.S. Bureau of Economic Analysis. 1997. "Real Total Gross Domestic Product for Utah." FRED, Federal Reserve Bank of St. Louis. January 1, 1997. https://fred.stlouisfed.org/series/UTRGSP.

———. 2018. "Real Gross Domestic Product per Capita." FRED, Federal Reserve Bank of St. Louis. December 27, 2018. https://fred.stlouisfed.org/series/A939RX0Q048SBEA.

U.S. Bureau of the Census. 1900. "Resident Population in Utah." FRED, Federal Reserve Bank of St. Louis. January 1, 1900. https://fred.stlouisfed.org/series/UTPOP.

U.S. Energy Information Administration—emissions. 2018. "State Carbon Dioxide Emissions Data." 2018. https://www.eia.gov/environment/emissions/state/.

U.S. Energy Information Administration—energy consumption. 2018. "Utah—SEDS—U.S. Energy Information Administration (EIA)." https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_use/total/use_tot_UTcb.html&sid=UT.

Yong, Ed. 2020. "How the Pandemic Defeated America." *The Atlantic*, September 2020. https://www.theatlantic.com/magazine/archive/2020/09/coronavirus-american-failure/614191/.