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The Limits to Growth model: still prescient 50 years later

Gaya Herrington
Vice president of ESG Research at Schneider Electric and member of The Club of Rome's Transformational Economics Commission

Earth 4All

The 1972 bestseller *The Limits to Growth* (LtG) concluded that if humanity kept pursuing economic growth without regard for environmental costs, global society would decline sharply within the first half of the 21st century, potentially leading to collapse. Its authors (Meadows, Meadows, Randers & Behrens III) predicted that – without change – available food, standards of living, and ultimately the human population would all diminish.

The LtG authors used a model called World3 to study key interactions between global variables for population, fertility, mortality, industrial output, food availability, public services, non-renewable resources and pollution. World3 is based on the work of Forrester (e.g. 1971; 1975), at the time a professor at Massachusetts Institute of Technology and the founder of system dynamics (SD) modelling. SD is an approach for modelling interactions between parts of a system that often produce non-linear behaviour, such as delays, feedback loops and exponential growth or decline. The same technique is used for the Earth4All model, a more recent model that supports the recommendations outlined in the book *Earth for All: A plan for global wellbeing on a healthy planet* to be published in 2022. In fact, Jorgen Randers, the creator of the Earth4All model, was one of the LtG authors.

In their original work, Randers and the LtG team generated scenarios for global developments with World3 by varying assumptions about technological innovation and adoption, amounts of non-renewable resources and societal priorities. Some scenarios ended in sharp declines of human systems. These "collapses" did not mean that humankind would cease to exist altogether, just that next generations would be significantly worse off than the previous ones. Another scenario – based on a different set of assumptions – produced a "stabilised world" (SW) in which collapse was avoided and standards of living remained high. This SW scenario deviated significantly from historical trends, however. Concerningly, the scenario based solely on historical averages, called "business as usual" (BAU), was among those ending in societal collapse. Given this prospect, I decided in 2020 to conduct a quantitative comparison between empirical data and the most recent version of World3 scenarios. (The authors had recalibrated their model in 1992.) Had humanity done better over recent decades, or were we still following BAU?

What I did

I compared empirical data with four scenarios from the latest version of World3, which was the recalibrated 1992 version with two variables added in 2004 (scenarios 1, 2, 6 and 9 in the 30-year update to LtG in 2004):

- **The best-known "business as usual" (BAU)**
- **"Business as usual 2" (BAU2)**
- **"Comprehensive technology" (CT)**
- **"Stabilised World" (SW)**

The assumptions underlying each scenario span a range of technological, social and resource conditions. In each scenario, the cause of decline differs and its scale varies from a temporary dip to societal collapse (see Figure 1). I chose BAU, BAU2, CT and SW because together they form a comprehensive set of "stories", representing prevalent narratives that people share and operate through with each other today.

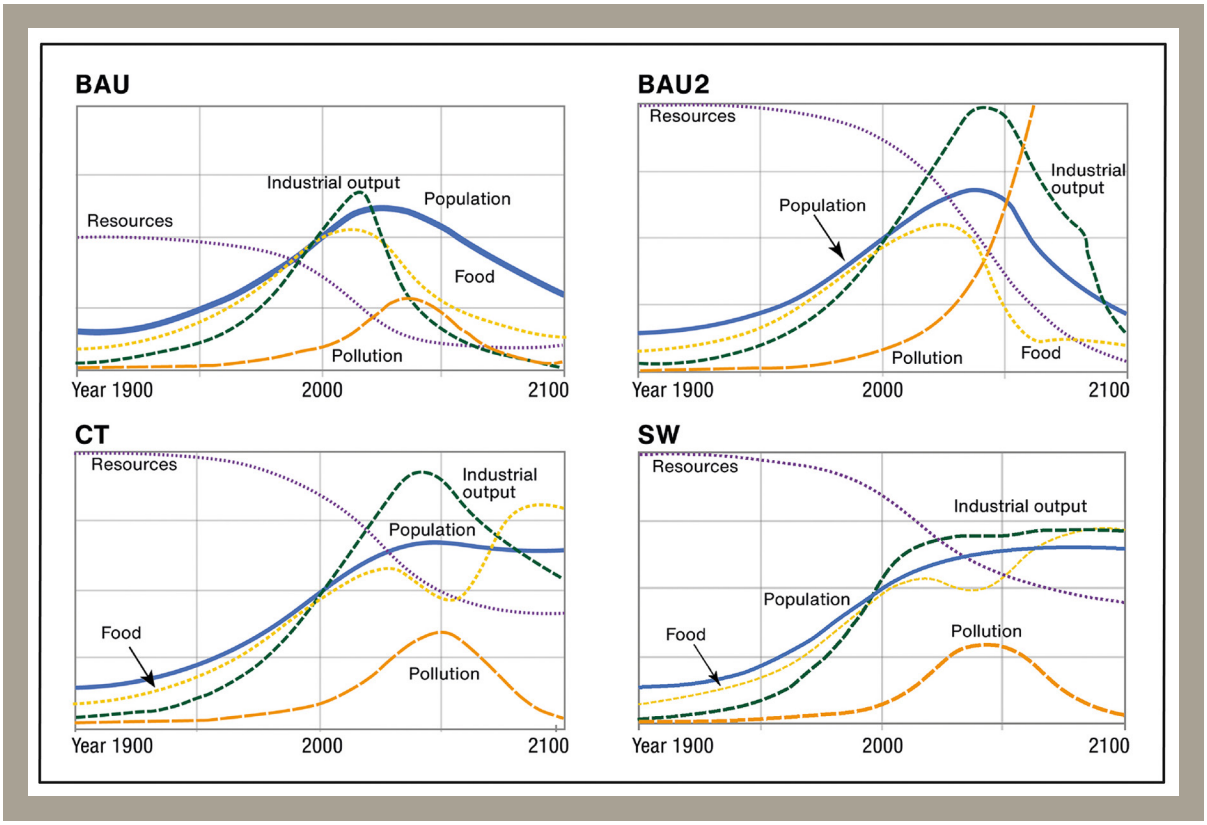

Figure 1. BAU, BAU2, CT and SW scenarios of the 2004 *The Limits to Growth* book. Graphs by Hillary Moore.

As mentioned, the BAU scenario was based solely on historical averages without any assumptions. In that way, it represents the "we can keep growing forever!" attitude that is tacitly ubiquitous in society. In BAU, the relentless pursuit of growth continues until resource scarcity causes a collapse.

BAU2 is also business as usual, but with double the natural resources. This scenario was added by the LtG authors to the later version to address criticism that natural resources had turned out to be more abundant than estimated in the 1970s. More abundant resources do not avoid a collapse in this World3 scenario; the cause of the collapse merely changes from a resource scarcity crisis to a pollution crisis. With the resource constraint relaxed, incentives to change societal priorities are reduced, so business as usual goes on for longer. This creates so much pollution that agricultural output and human health plummet after a breakpoint, and because business as usual went on for longer, the collapse is even steeper than in BAU. BAU2 essentially tells the story of ecosystem breakdown from accumulated pollution, including the effects of climate change driven by anthropogenic greenhouse gases. In this sense, BAU2 can be regarded as the climate change approximate scenario.

CT represents the technologist's belief in humanity's ability to innovate out of environmental constraints. In this scenario, assumptions include unprecedented technological innovation in a world that otherwise does not change its ultimate goal of growth. The innovation rate in pollution abatement, food production and resource efficiency is set much higher than historical averages, and the technology is assumed to be shared across the globe – including with those who cannot pay for it. The technological solutions do in fact help avoid an outright collapse. However, CT still results in some declines because so many resources need to be diverted towards technological innovation that not enough remain for agricultural production and health and education services.

In SW, humanity consciously lets go of continuous expansion as its ultimate pursuit. We shift societal priorities away from material consumption and industrial growth towards health and education services, as well as pollution abatement and resource-efficient technologies. In essence, society consciously limits its material footprint and shifts priorities towards meeting human needs and protecting the environment. This avoids collapse and leaves humanity with the highest levels of welfare. The four scenarios are summarised in the table below.

Scenario	Assumptions	Cause
BAU	No assumptions added to historical averages.	Collapse due to natural resource depletion.
BAU2	BAU + double the natural resources.	Collapse due to pollution (climate change approximate).
CT	BAU2 + exceptionally high technological development and adoption rates.	Rising costs for technology eventually cause declines, but no collapse.
SW	CT + changes in societal values and priorities.	Population stabilises in the 21st century, as does wellbeing on a high level.

Table 1. Assumption description and cause of halt in growth and/or decline per scenario.

I collected real-world data for the following World3 variables: population, fertility, mortality, pollution, industrial output, food, health and education services, non-renewable natural resources, human welfare, and ecological footprint. This data came from academia, government agencies, non-government organisations, United Nations entities and the World Bank. I plotted the empirical data together with the variable for each of the four scenarios. These plots gave good impressions of how closely empirical data aligned with the four scenario paths over time, but I also used statistical measures (a normalised root mean square error and a combination of the value difference and difference in rate of change) to validate what I observed in the graphs.

What I found

The graphs for every variable can be found in my article (Herrington, 2020), or my 2022 book *Five Insights for Avoiding Global Collapse*. Most show an image similar to the one below (Figure 2). Overall there was close alignment of empirical data with each of the four scenarios. BAU2 and CT aligned with observed data most closely, SW diverged the most and BAU tracked in between. BAU2 and CT both aligned equally close because the two scenarios only start to diverge after 2020.

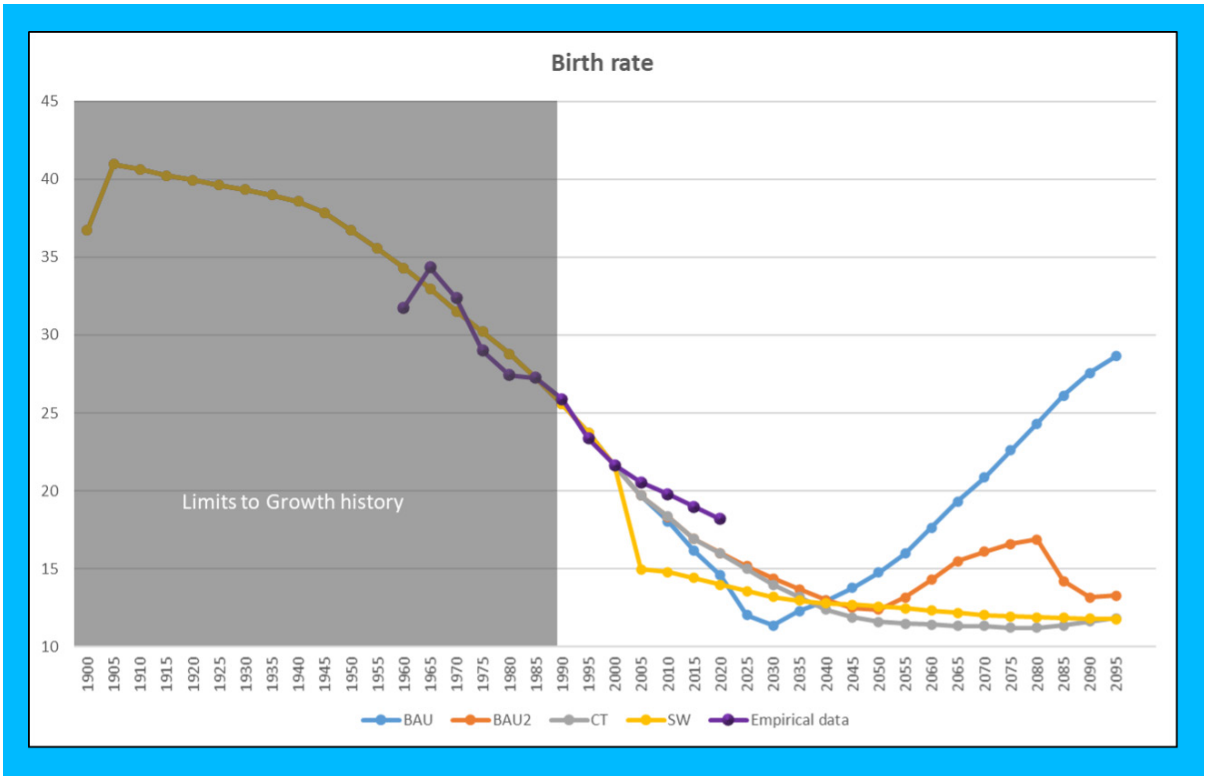

Figure 2. Empirical data for birth rate (births per 1,000 people) and the variable for each scenario.

World3 was pretty good

The overall close alignment of empirical data with each of the four scenarios is a testament to the accuracy of World3. It received a lot of criticism at the time, most of it from people misunderstanding the book's message or the new modelling technique. Some of this criticism had validity; after all, no model is perfect and thus no conclusion drawn from its output is indisputable.

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But a lot of the criticism really wasn't justified. Critics, such as Passell, Roberts and Ross (1972) and Bailey (1989), claimed that BAU showed a collapse from resource depletion by 1990, or that all scenarios ended in collapse, or that the models only run to 2040. By looking at the pictures in the book, one could have concluded that, in fact, all scenarios run to 2100, they do not all end in collapse, and the ones that do only showed steep decline setting in after 1990. Yet, by the turn of the century, these claims had been so effective as to convince almost everyone that LtG had been relegated to, as Lomborg and Rubin put it in 2009, "the dustbin of history". Perhaps that's why so few people bothered to check the scenarios. To say this is a shame is an understatement. No other 20th-century model seems to have forecast so accurately decades into the future. We will never know, but I believe global society would be in a better state had we heeded the powerful message that LtG already provided us with 50 years ago.

Technology will not save us if we don't want to save each other

One of the key messages of LtG that was almost completely missed was the final "s" in limits – plural. Sure, we can innovate ourselves out of one limit, because indeed, humanity is ingenious. But inevitably we will run into another limit. That is why collapse keeps occurring in the scenarios; all that changes is its cause. Put another way, we can either recognise human and planetary limits – as in the SW scenario – or we will have limits forced upon us.

BAU not aligning most closely with empirical data does not mean that societal collapse can be ruled out. It's important to note that the scenario with the smallest declines, SW, aligns with empirical data the least. Furthermore, one of the best-fit scenarios, BAU2, shows a collapse pattern. And the BAU2 story sounds eerily familiar. Although we're seeing increased scarcity of natural resources today, it's true that the resource scarcity fears of the 1970s did not fully materialise. But that's because we used our innovative abilities to discover and extract more dispersed fossil reserves. This has kept us weaned on fossil fuels for longer and as a result humanity is facing ecosystem collapse from climate change, other pollution and biodiversity loss. In short, we innovated ourselves out of the resource limit only to bump into the pollution limit.

Some might argue that we're probably following the CT scenario instead of BAU2. People might look at Figure 1 thinking that we can hold on to growth as a goal while basically being fine with only a temporary dip in welfare levels around 2050. Those people wouldn't be alone: many bet

on technology solving our environmental problems. But it is an enormous gamble, given the odds and the urgency of the situation. What's more, LtG is far from the only study indicating severe risks of ecosystem breakdown. Reports from the Intergovernmental Panel on Climate Change, the planetary boundaries studies, the Ecological Footprint and much other research all tell us the same message: we can't go on like this.

Of course, technology will have to be a vital part of the sustainability revolution. But it will not transform our society unless we want it to, that is to say, unless we change society's priorities. Technology is not a divine power, it's a tool. Tools developed within a system will aim to support that system's goal. As long as our society pursues growth, our technological innovations will mostly serve this pursuit. That's why I typically avoid diving into the details of why I think that the assumptions underlying the CT scenario are unrealistic. It obscures the question we really should be asking: do we want to be following the CT scenario in the first place? Why would we use our innovative powers to invent robot pollinators to replace bees if we also have the choice to invent agricultural practices that do not have the side effect of insecticide? Why use drones to plant new trees when we could also redesign our economy so that existing forests are not cut and burned down? Why bet against the odds on technology to magically deliver us from collapse when we can consciously choose to reshape global society to bring us back from the precipice?

Now or never

This may have been the most often missed part of the LtG message: the vision for a better world. LtG was a warning, but not a message of doom. And neither is the message of my research. True, one of my conclusions is that we are living in a now or never moment in history. An update of this comparison in another few years might be able to identify one specific closest fit to empirical data, but I do not recommend we wait for that. The BAU2 scenario shows a halt in the hitherto continuous increase in global welfare levels around the year 2030, and collapse setting in around 2040. This indicates we must act now before we reach the turning point. We cannot wait for the data to show that – surprise – as it turns out, infinite growth on a finite planet is not possible.

The Limits to Growth was a warning, but not a message of doom.

However, the LtG study also offered a way forward with SW. Likewise, my research shows that it's not too late to realign ourselves with this scenario, in which a decline in welfare levels within this century is minimised (Figure 3). The close alignment to empirical data, and the fact that the four selected scenarios have not yet diverged significantly, together form a call to action. The message is clear: it's not yet too late for humankind to change course, but the window of opportunity is closing fast. And despite what some claim, the technology-centric CT scenario is not our only choice. Instead, we can deliberately discard growth as society's ultimate goal. Not as a capitulation to grim necessity but because we can – and want to – do better. The LtG graphs show how society would be more stable in the SW scenario, but not how much more its citizens and their natural surroundings

would be thriving. A data analysis cannot convey humans' innate love for nature, and how we hurt when we lose parts of it forever. A number between 0 and 1 on a welfare index cannot fully capture how much happier and more connected people would feel in a world that prioritises meeting everyone's needs and enabling them to reach their full potential. But we can imagine.

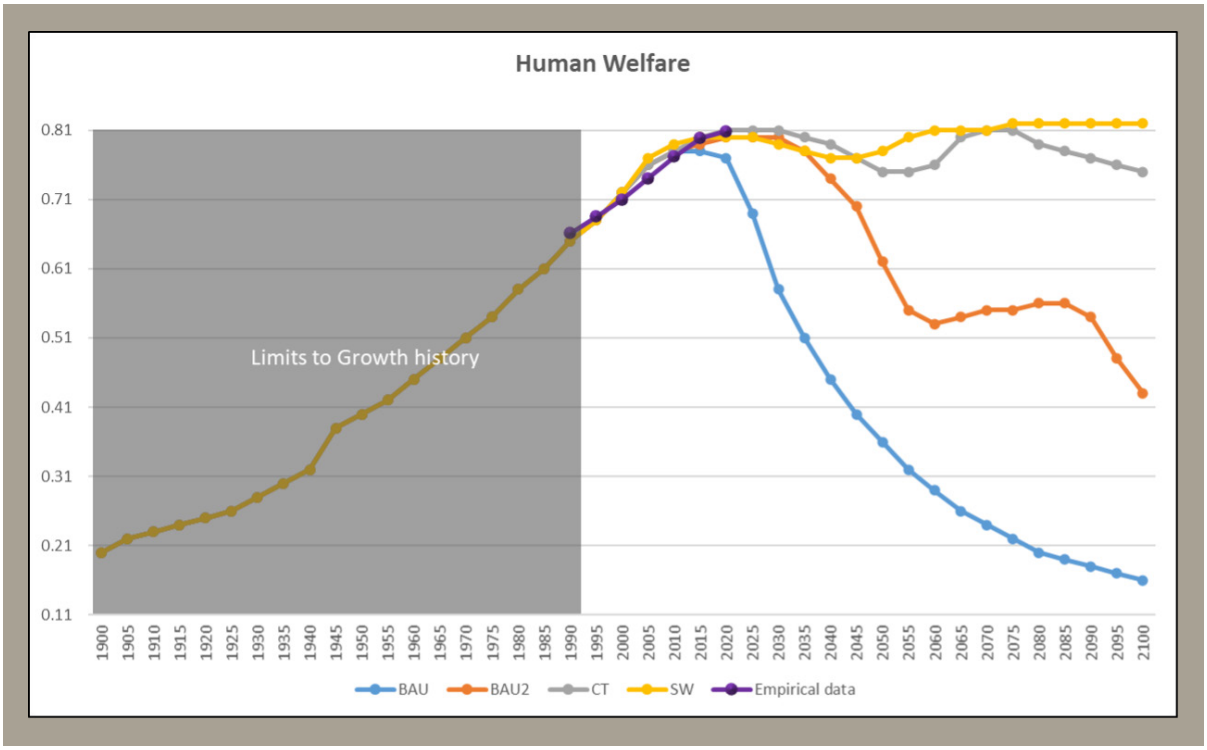

Figure 3. Empirical data (UN Human Development Index) plotted against human welfare variables for all four scenarios.

The Club of Rome's message today

Five decades ago, the report to The Club of Rome, *The Limits to Growth*, provided us with a vision for a better world. At the time, the transition to such a world could have been achieved with incremental change over time. The message was ignored and humanity is now on the brink of collapse. At the 50-year anniversary of LtG, there will be a new book and report to The Club of Rome – *Earth for All: A plan for global wellbeing on a healthy planet*. Its message is still realistic in the sense that it warns of risks that lie ahead if we hold on to business as usual. But even more, as it always was, it's a message of hope. We need to act fast, yes, but we are not out of time yet to turn society around. We are capable of better. In both publications the promise is the same: a planet for all where life can flourish indefinitely.

The recommendations in the 2022 book align closely with what World3 already showed us all those years ago. We should shift societal priorities from material consumption towards inclusive wellbeing while staying within planetary boundaries. Building upon World3, the Earth4All model has helped identify the leverage points in the global system that can transform our society in this

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way with sufficient speed. The *Earth for All* book also gives much more detail than LtG on how to do that, including by addressing regional and distributional factors. Because of course, growth will be necessary for those regions where large groups of people are not yet able to meet their basic needs, and growth will also inevitably happen in sectors such as renewable energy.

But growth can no longer be humanity's ultimate goal. For this century, we need a more ambitious and mature aim: to provide enough for each, in a way that can last. When discussing either the Earth4All or World3 scenarios, we are ultimately talking about values. This time in history is nothing less than a battle for humanity's soul. Now that humankind has attained global reach and unprecedented power to shape its destiny, limits to growth force upon us this question: who do we want to be and what world do we want to live in?

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Earth4All

Earth4All is an international initiative to accelerate the systems changes we need for an equitable future on a finite planet. Combining the best available science with new economic thinking, Earth4All was designed to identify the transformations we need to create prosperity for all. Earth4All was initiated by The Club of Rome, the Potsdam Institute for Climate Impact Research, the Stockholm Resilience Centre and the Norwegian Business School. It builds on the legacies of *The Limits to Growth* and the planetary boundaries frameworks.

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