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Scenarios for Future Global Growth to 2050

Charles Kenny and Zack Gehan

ABSTRACT

We develop scenarios for the shape of the global economy in 2050 building on a simple regression of the historic relationship between current income and lagged income, demographic features, climate, and education, using the coefficients to develop a "central" forecast and error terms to set high and low bounds on country outcomes. Scenarios examine combinations of low and high outcomes for different country groupings. "Central" forecasts suggest slowing per capita growth rates for high income countries as well as many upper middle income countries including China, with continued global income convergence. Scenario exercises suggest the potential for considerable variation in outcomes including global share of the economy and voting power in international institutions.

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1 Introduction

Forecasts of the future shape of the global economy, if they are at least broadly accurate, can help inform planning and policy discussions in areas from global governance through business expansion plans. A recent area of particular focus has been around climate change, which has created a new demand for forecasts as inputs to both emissions and impact models.

At the same time, this relies on forecasts in fact being 'broadly accurate,' which turns out to be difficult, because growth outcomes are unstable, driven by unpredictable shocks.[1] Short-term (yearly) expert forecasts do appear to contain significant value over naïve forecasts (potentially in part because they influence behavior).[2] But as the forecast period becomes longer, it appears the signal to noise ratio declines. IMF five-year forecasts of GDP growth are still more accurate than simply taking the last few years growth and assuming it will remain the same, but their error margin is about 84 percent as large as simple linear forecasting, they tend to over-predict growth, and display an inability to predict recessions.[3]

Longer term forecasts are at least plausibly linked to even greater inaccuracy, and anecdotal evidence suggests they are frequently very wide of the mark—although one analyst has claimed long term forecasts made in the 1970s by the Club of Rome have held up reasonably well.[4] Some limited solace for long-term forecasters is provided by evidence of considerable regression to the mean in growth rates.[5]

Given uncertainty, a scenario process is attractive for creating a range of plausible outcomes, in part to distinguish closer-to-certainties and more-likely-unknowns about the future. Such a process is central to perhaps the most high-profile set of forecasts for the global change over the next century: the Shared Socioeconomic Pathways (SSPs) used by the Intergovernmental Panel on Climate Change.

The SSP narratives suggested differing rates of fertility, migration, mortality, education and so on.[6] Repeated expert group meetings developed forecasts for these variables based on the

[1] Easterly, W., Kremer, M., Pritchett, L., & Summers, L. H. (1993). Good policy or good luck?. *Journal of monetary economics*, 32(3), 459-483. Patel, D., Sandefur, J., & Subramanian, A. (2021). The new era of unconditional convergence. *Journal of Development Economics*, 152, 102687.

[2] Allan, Grant J. "Evaluating the usefulness of forecasts of relative growth." (2012): 1-26.

[3] De Resende, C. (2014). An assessment of IMF medium-term forecasts of GDP growth. *IEO Background Paper No. BP/14/01 (Washington: Independent Evaluation Office of the IMF)*. See Morikawa, M. (2020). Uncertainty in long-term macroeconomic forecasts: Ex post evaluation of forecasts by economics researchers. *The Quarterly Review of Economics and Finance* on decade forecasts made in 2006 being significantly upwardly biased.

[4] Kenny, C., & Williams, D. (2001). What do we know about economic growth? Or, why don't we know very much?. World development, 29(1), 1-22. Branderhorst, Gaya. 2020. Update to Limits to Growth: Comparing the World3 Model With Empirical Data. Master's thesis, Harvard Extension School. We will find out soon enough if Limits to Growth truly holds up: 2020 to 2030 is a period of dramatic economic collapse in two of the Club of Rome scenarios.

[5] Pritchett, L., & Summers, L. H. (2014). Asiaphoria meets regression to the mean (No. w20573). National Bureau of Economic Research.

[6] Here, for example, is the narrative for 'sustainability' SSP: "The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Increasing evidence of and accounting for the social, cultural, and economic costs of environmental degradation and inequality drive this shift. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and international organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading to a relatively low population. Beginning with current high-income countries, the emphasis on economic growth shifts toward a broader emphasis on human well-being, even at the expense of somewhat slower economic growth over the longer term. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Investment in environmental technology and changes in tax structures lead to improved

narratives.[7] Additional assumptions based on historical data were used to generate rates of physical capital stock growth and total factor productivity convergence under each narrative. In turn, estimates for these variables were used to generate predictions of GDP and GDP per capita for world regions out to 2100.[8] (There may be some irony in the fact that SSP forecasts do not (yet) specifically account for the impact of climate change on those outcomes).

Long term economic scenario development has a history predating the SSPs: perhaps most well-known is the Shell PLC (previously Royal Dutch Shell) series. Their 1992 scenario exercise produced two alternate futures: *New Frontiers*, where liberalization and globalization speeds growth in poor countries and rapid convergence results; and *Barricades*, where globalization unwinds.[9] Under *New Frontiers*, the share of global GNP (PPP) controlled by the OECD was predicted to fall from 54% to 30% 1990-2020. Under *Barricades*, the PPP GNP per capita of OECD countries was expected to rise from $12,500 to $25,000 1990-2020 (in 1990 dollars) while the GNP per capita of the rest of the world would rise from $2,500 to $5,000 (i.e. both would approximately double).[10] Using constant data from the World Bank and recent PPP data (2017), the OECD share PPP GNI has fallen from of 64% in 1995 to 46% today while OECD GNI per capita climbed 45% 1990-2020 and non-OECD countries by 130% 1995-2020.[11] Successfully for a scenarios process, the outcome regarding global share of GDP was slightly less positive than the positive scenario, and GNP per capita performance for non-OECD countries was less negative than the negative scenario. But the OECD per capita growth performance was actually even worse than the negative *Barricades* scenario could imagine.

In this paper, we follow the Shell scenarios team and the IPCC in embracing the uncertainty of growth outcomes to develop potential scenarios for the world economy (in our case to 2050), but use a simpler approach. We develop a model to predict incomes per capita based on historical data on income, demographic factors, education and climate, and then use forecast input values to create a central estimate of incomes in 2050. We use error terms from the model to develop scenarios for the

resource efficiency, reducing overall energy and resource use and improving environmental conditions over the longer term. Increased investment, financial incentives and changing perceptions make renewable energy more attractive. Consumption is oriented toward low material growth and lower resource and energy intensity. The combination of directed development of environmentally friendly technologies, a favorable outlook for renewable energy, institutions that can facilitate international cooperation, and relatively low energy demand results in relatively low challenges to mitigation. At the same time, the improvements in human well-being, along with strong and flexible global, regional, and national institutions imply low challenges to adaptation." See Brian C. O'Neill, Elmar Kriegler, Kristie L. Ebi, Eric Kemp-Benedict, Keywan Riahi, Dale S. Rothman, Bas J. van Ruijven, Detlef P. van Vuuren, Joern Birkmann, Kasper Kok, Marc Levy, William Solecki, The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century, Global Environmental Change, Volume 42, 2017, Pages 169-180. See for a description of the overall process: Keywan Riahi, et al,The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, Global Environmental Change, Volume 42, 2017, Pages 153-168.

[7] S. KC, W. Lutz The human core of the shared socioeconomic pathways: population scenarios by age, sex and level of education for all countries to 2100 Global Environ. Change, 42 (2017), pp. 181-192.

[8] Leimbach, M., Kriegler, E., Roming, N., & Schwanitz, J. (2017). Future growth patterns of world regions–A GDP scenario approach. Global Environmental Change, 42, 215-225. Cuaresma, J. C. (2017). Income projections for climate change research: A framework based on human capital dynamics. Global Environmental Change, 42, 226-236. Rob Dellink, Jean Chateau, Elisa Lanzi, Bertrand Magné. Long-term economic growth projections in the Shared Socioeconomic Pathways, Global Environmental Change, Volume 42, 2017, Pages 200-214, follow a broadly similar approach but add fossil fuel reserves as a growth determinant.

[9] Available here: https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/new-lenses-on-the-future/earlier-scenarios.html

[10] These numbers based on eyeballing the graphs in the text.

[11] This does not allow for countries joining the OECD since 1990. Series from the World Bank to calculate numbers: SP.POP.TOTL, NY.GNP.PCAP.PP.KD, numbers for OECD and World. (Might be best to have this calculation in a script for replicability)

shape of the global economy in 2050, including distribution of global output, poverty rates, energy use and military spending. We hope to provide a robustness check with regard to the plausibility of SSP scenarios and other existing forecasts as well as an application to a set of issues including global poverty dynamics and multiliateral governance.

2 Variables to Forecast GDP/Capita and Excluded Factors

The cross-country growth regression literature has fallen somewhat out of fashion (with some good reason). Google Ngrams suggest "J-PAL" overtook "growth regression" in its corpus in 2016.[12] But it has left a legacy of hundreds of variables that are at least partial correlates of growth at least in some datasets, periods, variable combinations and regression models.[13]

Most of those variables are unsuited to a forecasting exercise because we cannot predict their future values with any accuracy, but even beyond unchanging historical and geographic features, we do have some variables that are predictable (or at least are widely predicted). Before turning to demographic, climate and educational factors that we do include, it is worth discussing some previously forecasted growth correlates and fixed features we exclude, and our reasons for doing so.

Uri Dadush and Bennett Stancil produce economic forecasts based on a Cobb-Douglass function, taking a growth rate of capital based on current investment rates and a convergence toward an average investment rate of 20 percent by 2050, alongside measures of current education, infrastructure and policy to set a 'convergence conditions index,' and population forecasts from the US Census Bureau, all of this entered into an equation with the gap between income of the forecast country and the income per capita of the US at the time.[14] Cuaresma, Leimbach and colleagues use a broadly similar set of data and approach to help power their SSP forecasts, accounting for scenario assumptions by altering forecast changes in population, technology growth, capital accumulation and fixed effects.[15]

We hew to a simpler model because these approaches force a number of assumptions about TFP growth and capital stock that are considerably open to policy influence.[16] We want a model suitable for building scenarios from, rather than embedding assumptions about future policy change into the forecasting process. Below, we turn to the set of forecastable indicators with good cross-country and time series coverage that we incorporate into our model, but before that it is worth explaining why our core model excludes 'forecastable' historic factors.

[12]There are good reasons for the decline: Durlauf, Steven N., Paul A. Johnson, and Jonathan RW Temple. "Growth econometrics." Handbook of economic growth 1 (2005): 555-677. Kenny, C., & Williams, D. (2001). What do we know about economic growth? Or, why don't we know very much?. World development, 29(1), 1-22.

[13]Sala-i-Martin, X. (1997). I just ran four million regressions. Eberhardt, M.,& Teal, F. (2011). Econometrics for grumblers: a new look at the literature on cross-country growth empirics. Journal of economic Surveys, 25(1), 109-155.

[14]Dadush, U. B., & Stancil, B. (2010). The world order in 2050. Washington, DC: Carnegie Endowment for International Peace. A further example is Lindh and Malmberg, who use the share of young and old populations to help predict convergent global growth trends to 2050. Lindh, T., & Malmberg, B. (2007). Demographically based global income forecasts up to the year 2050. International Journal of Forecasting, 23(4), 553-567.

[15]Cuaresma, J. C. (2017). Income projections for climate change research: A framework based on human capital dynamics. Global Environmental Change, 42, 226-236. The 'reverse engineering is accomplished by taking their basic results and incorporating SSP narrative storylines by shifting population and education dynamics, the assumed growth rate of TFP, altering country fixed effects and changing the modeled path of capital accumulation.
Leimbach, M., Kriegler, E., Roming, N., & Schwanitz, J. (2017). Future growth patterns of world regions–A GDP scenario approach. Global Environmental Change, 42, 215-225.

[16]Note also Cuaresma's calibration regressions suggest changes in his capital stock measures are not significantly related to changes in income per capita.

Growth regressions frequently incorporate indicators including legal origins, historical measures of ethnolinguistic fractionalization, the straightness of borders, settler mortality, colonial history, date of independence and genetic inheritance, usually in an effort to reflect slow-changing cultural and institutional features potentially linked to low growth.[17] We worry that including such variables, even though they are often correlated with past growth, risks locking in at least some degree of bad luck as a predictor of future fortune in a process that appears to be highly stochastic even over longer periods.[18] Nonetheless, we do run a version of our core regression with fixed country effects as a robustness exercise.

2.1 Included Forecast Variables

Excluding these factors leaves us with a model based on past income, demographics, climate and education. Including initial income helps to account for convergence, with conditional convergence (slower growth in richer countries in the presence of control variables) being one of the strongest results in the growth literature.[19] Our initial model also had a gravity-weighted measure of GDP per capita for all other countries as an additional convergence variable, based on previous studies suggesting the importance of neighborhood effects, but it did not enter significantly.[20]

Looking at demographics, a lower share of the working age population is a mechanical cause of a lower GDP per capita level because total population includes non-working dependents as well as workers. But the 'demographic dividend' literature has illustrated a broader association between a declining child dependency ratio and growth not just through the proportion of the population of working age but also impacts on female labor force participation.[21]

A smaller working age population due to aging also appears associated with growth effects. Maestas et al suggest that two-thirds of the reduction in growth rates they associate with declining labor force growth in the US is due to slower productivity growth rather than the direct effect of fewer workers.[22] Potential mechanisms include an association between an aging workforce and lower innovative capacity, reduced savings, and reduced new enterprise creation.[23] Note also older

[17] Alesina, A., Easterly, W., & Matuszeski, J. (2011). Artificial states. Journal of the European Economic Association, 9(2), 246-277. Easterly, W., Ritzen, J., & Woolcock, M. (2006). Social cohesion, institutions, and growth. Center for Global Development Working Paper, (94). La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2008). The economic consequences of legal origins. Journal of economic literature, 46(2), 285-332. Acemoglu, D. (2010). Growth and institutions. In Economic Growth (pp. 107-115). Palgrave Macmillan, London. Kenny, C. (1999). Why aren't countries rich?: Weak states and bad neighbourhoods. The Journal of Development Studies, 35(5), 26-47. Grier, R. M. (1999). Colonial legacies and economic growth. Public choice, 98(3), 317-335. Bove, V., & Gokmen, G. (2018). Genetic distance, trade, and the diffusion of development. Journal of Applied Econometrics, 33(4), 617-623.

[18] Easterly, W., Kremer, M., Pritchett, L., & Summers, L. H. (1993). Good policy or good luck?. Journal of monetary economics, 32(3), 459-483.

[19] Kremer, M., Willis, J., & You, Y. (2022). Converging to convergence. NBER Macroeconomics Annual, 36(1), 337-412.

[20] The weighting was GDP over distance squared, and the intuition that countries surrounded by large rich countries might grow faster than those surrounded by small, poor ones. Results on request. Previous studies that have found a neighborhood convergence effect include . Kenny, C. (1999). Why aren't countries rich?: Weak states and bad neighbourhoods. The Journal of Development Studies, 35(5), 26-47.

[21] Bloom, D., Canning, D., & Sevilla, J. (2003). The demographic dividend: A new perspective on the economic consequences of population change. Rand Corporation. Note however critiques: Lutz, W., Crespo Cuaresma, J., Kebede, E., Prskawetz, A., Sanderson, W. C., & Striessnig, E. (2019). Education rather than age structure brings demographic dividend. Proceedings of the National Academy of Sciences, 116(26), 12798-12803.

[22] The Effect of population aging on economic growth, the labor force and productivity, Nicole Maestas Kathleen J. Mullen David Powell Working Paper 22452.

[23] Vollrath, D. (2020). Fully Grown: Why a Stagnant Economy is a Sign of Success. University of Chicago

populations tend to demand more services, which see lower productivity growth.

Because many of those who will be part of future age cohorts have already been born, demographic trends are comparatively easy and accurate to forecast over a period of a few decades. For example, in 1958, UN population forecasters predicted a world population of about 6.3 million in 2000, the real number was 6.1 million, which was first forecast in 1966 (although forecast accuracy for 2000 sadly got somewhat worse in most of the intervening period until as late as 1997).[24] Demographic forecasts have been widely used in existing economic forecast exercises, as we have seen.

We take the UN central forecast for population to 2050, both as our total population forecast and population share data. UN probabilistic estimates for the world as a whole suggest 80 percent of forecasts fall within a range of about 700 million people in 2050, while the SSP process has produced a range of forecasts that see world population vary by as much as 1.5 billion in that year.[25] There is certainly some uncertainty which we try to address in the robustness section.

Despite skepticism about the returns to education absent an institutional environment that would guarantee learning and a profitable, socially useful exploitation of learning,[26] years of education in the adult population has been a staple of cross-country growth regressions, and a number of recent additions to the literature do suggest a link with growth.[27] Furthermore, trends in education growth are reasonably forecastable, in part because education stocks depend considerably on education that has already happened, but also because the growth of enrollment follows a stable pattern across countries over time.[28]

For historical data we use Barro and Lee's dataset of average years of education in the adult population (aged 15-64). Barro and Lee's data has significant coverage gaps, however, especially for African countries including Nigeria and Ethiopia. We use Nardelli et. al.'s estimates (in some cases based on additional research that uncovered statistics, but in many cases based on comparing schooling patterns to countries in the same region with similar incomes) to fill in gaps in educational attainment.[29] Note that for the 2020 data in the regression we used a linear projection from available 2010 and 2015 data.

We develop our own simple forecast for 2030-50 for average years of education in the population

Press. P. 144, 148. Liang, J., Wang, H., & Lazear, E. P. (2018). Demographics and entrepreneurship. Journal of Political Economy, 126(S1), S140-S196. Aiyar, M. S., & Ebeke, M. C. H. (2016). The impact of workforce aging on European productivity. International Monetary Fund. Lisenkova, K. (2020). Demographic ageing and productivity. In Productivity Perspectives. Edward Elgar Publishing. Calvino, F., C. Criscuolo and R. Verlhac (2020), "Declining business dynamism: Structural and policy determinants", OECD Science, Technology and Industry Policy Papers, No. 94, OECD. Lui, S., Black, R., Lavandero-Mason, J., & Shafat, M. (2020). Business Dynamism in the UK: New Findings Using a Novel Dataset (No. ESCoE DP-2020-14). Economic Statistics Centre of Excellence (ESCoE).

[24] Keilman, Nico. "Erroneous population forecasts." Old and New Perspectives on Mortality Forecasting 95 (2019). It is worth noting recent UN forecasts for China have been particularly scrutinized and debated, with forecasts varying by as much as 100 million from the UN central estimate by 2050. Dai, K., Shen, S. & Cheng, C. Evaluation and analysis of the projected population of China. Sci Rep 12, 3644 (2022)

[25] S. KC, W. Lutz The human core of the shared socioeconomic pathways: population scenarios by age, sex and level of education for all countries to 2100 Global Environ. Change, 42 (2017), pp. 181-192

[26] Pritchett, L. (2001). Where has all the education gone?. The world bank economic review, 15(3), 367-391.

[27] Benos, N., & Zotou, S. (2014). Education and economic growth: A meta-regression analysis. World Development, 64, 669-689. The demography of educational attainment and economic growth W. Lutz, J. Crespo Cuaresma and W.C. Sanderson Science, 319 (2008), pp. 1047-1048

[28] Clemens, M. A. (2004). The Long Walk to School: International education goals in historical perspective. Center for Global Development Working Paper, (37).

[29] Peter Nardulli Buddy Peyton Joe Bajjalieh (2012) Gauging Cross-National Differences in Education Attainment Cline Center for Democracy, University of Illinois at Urbana-Champaign Committee on Concepts and Methods Working Paper Series 57.

based on current levels, as described in the next section. For robustness, regarding both education and population, we also use forecasts developed by the Wittgenstein Center for Demography and Global Human Capital as part of the SSP process.[30]

Regarding climate change (and specifically temperature), a review of the literature regarding the past impact of temperature (often controlling for precipitation) suggests global GDP will be 1-3 percent lower in 2100 due to the impact of climate change, consistent with most integrated assessment models. These effects are larger in poor countries and (relatedly) in agriculture,[31] and some studies (including Khan et. al. and Burke et. al.) suggest global GDP will be between 7 and 23 percent lower at century's end than it would have been absent climate change.[32]

That said, effects are concentrated so that under more pessimistic models some African countries are forecast to be potentially poorer in 2100 than today due to the impact of climate change. Again, Dang and colleagues' review suggests "while the effects of warming temperature on poverty are strongly observed using analysis at the subnational level, such effects are not easily discernible based on similar analysis at the country level,"[33] suggesting subnational analysis could generate both more heterogeneous effects but also ones larger in the aggregate. (It is also important to note that climate change will have considerable effects not captured in long term GDP trends including far greater income volatility in some countries and non-market effects.)

The impact of climate change on growth remains challenging to incorporate in a forecast. Temperature data displays high variability around a trend (and in most studies of the growth impact of climate it is this variation from trend that drives estimates of impact), while forecast temperatures are based on the trend. In addition, we are exiting historical temperature ranges, making past change a poor guide to future outcomes, and this is compounded by the increasing risk of tail events that could lead to dramatic economically significant impacts.[34] Effects extend far beyond temperature—to more violent cyclones, for example—which are harder to predict but might have large impacts on some countries.[35]

It is widely agreed by both modelling and existing forecasting exercises that the larger impact

[30]Lutz, W., Goujon, A., Kc, S., Stonawski, M., & Stilianakis, N. (2018). Demographic and human capital scenarios for the 21st century: 2018 assessment for 201 countries. Publications Office of the European Union.

[31]Newell, R. G., Prest, B. C., & Sexton, S. E. (2021). The GDP-temperature relationship: implications for climate change damages. Journal of Environmental Economics and Management, 108, 102445.

[32]Kahn, M. E., Mohaddes, K., Ng, R. N., Pesaran, M. H., Raissi, M., & Yang, J. C. (2019). Long-term macroeconomic effects of climate change: A cross-country analysis (No. w26167). National Bureau of Economic Research. Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(7577), 235-239. The latest IPCC (AR6) synthesis report suggests 4 degree warming could have an impact on GDP equivalent to that of the recent global pandemic –again suggesting that climate change would reduce global GDP in 2100 by a few percentage points relative to a scenario with no climate change. Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., ... & Birkmann, J. (2022). Climate change 2022: Impacts, adaptation and vulnerability. IPCC Sixth Assessment Report.

[33]Dang, H. A., & Trinh, T. A. (2022). Does Hotter Temperature Increase Poverty? Global Evidence from Subnational Data Analysis. Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527(7577), 235-239. Azzarri and Signorelli's results suggest 'strongly observed' may be an exaggeration, however: they look at subnational outcomes for Sub Saharan Africa and find that excess rainfall causes increased poverty and reduced consumption but that "extreme shortages of rain and heat shocks show an uncertain effect, even when estimates control for spatial correlation between welfare and weather conditions" Azzarri, C., & Signorelli, S. (2020). Climate and poverty in Africa South of the Sahara. World development, 125, 104691.

[34]Pindyck, R. S. (2013). Climate change policy: what do the models tell us?. Journal of Economic Literature, 51(3), 860-72.

[35]Hsiang, Solomon M., and Amir S. Jina. The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones. No. w20352. National Bureau of Economic Research, 2014.