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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.

of climate change is concentrated after 2050, when our forecasts end, and (particularly with regard to the longer term) the extent of temperature change is obviously significantly influenced by policy choice.[36] Again, the national level is an unsuitable aggregate to discern impact given considerable subnational variation in climate outcomes.

With all of these caveats, we use a measure of annual average temperature over thirteen degrees centigrade (which takes the value zero if temperatures are below thirteen degrees) in our regression and forecasts, with the temperature scenario based on Representative Concentration Pathway 4.5.[37] As part of robustness exercises, we use temperatures associated with Representative Concentration Pathway 1.9 and 8.5—outlier pathways regarding future greenhouse gas concentrations utilized by the IPCC.

To add two further general caveats, historically there has been an association between slower growth and a large share of dependents, higher average temperatures and a more educated population. All three relationships make some theoretical sense, but they are nonetheless only correlational relationships. Using them to forecast the future at the very least demands the assumption that these variables remain causally related to growth or that underlying causal factors both remain correlated with our measures and themselves *causally* related to growth. Note it is also clear we are missing a number of other variables likely to be causally related to growth (we will see the R-squared of our base regression is only 0.13). In addition, we ran a number of different regressions before settling on this model (see Appendix Table One). The coefficients in some of these regressions are of notably different size and significance, with considerable implications for the core forecast.[38]

Table 1: Summary Statistics for Variables in the Core Model

	count	mean	sd	min	max
$\ln(\text{GDP/Capita})_t$ - $\ln(\text{GDP/Capita})_{t-10}$	995	0.21	0.38	−4.22	1.90
ln(GDP/Capita)	1193	8.82	1.24	5.53	12.56
% of Pop under 15	3200	27.05	11.58	9.31	51.57
% of Pop over 65	3200	12.93	10.24	0.69	47.77
ln(Avg. Years of School)	1250	1.52	0.90	−3.65	2.66
Degrees over 13C, RCP4.5	3872	4.53	5.85	0.00	17.88

[36] Tol, R. (2002). Estimates of the damage costs of climate change. Environmental and Resource Economics, 21(2), 135-160. Tol, R. S. (2021). The economic impact of weather and climate.

[37] We should report that in a previous levels regression we attempted to incorporate temperature (and interaction effects) into our baseline regression using multiple formulations, but failed to find significant results. While GDP per capita in a given year was negatively and significantly correlated with the square of temperature when prior year GDP per capita and temperature were also included in the regression, using ten year data (still 735 observations) up to 2010 (where we had real temperature data), the coefficients lost significance. Simply using temperature difference gave an insignificant coefficient with a positive sign, using level and square of temperature also failed. Using temperature change above 13 degrees as well as temperature change multiplied by lagged log income per capita produced coefficients significant at around the ten percent level in our core regression, but the coefficients implied that temperature increases above 13 degrees were associated with more rapid growth for nearly all countries. Temperature level above thirteen degrees and temperature level above thirteen degrees multiplied by the log of per capita income gave the most satisfactory results, but they were still statistically insignificant in our regression.

[38] Our final choice of indicators was based in part on theory (the fact that we could think of no theoretical reason why marginal education increases should lead to negative growth, for example), and that some versions produced central forecasts where high income countries were significantly poorer in 2050 than today potentially the result of out of sample values for demographic and education projections, not least. But this, we accept, implies that we engaged in a fishing expedition.

2.2 Other Data

Our selected income measure is PWT PPP GDP per Capita in 2017 international dollars. For 2020 numbers we use 2019 data rather than actual 2020 data both due to availability and to avoid both forecasts and the base regression being over-influenced by the impact of the Covid-19 pandemic.[39]

For other forecasts that build on our base model:

- For income distribution within countries, we use the World Bank's Poverty and Inequality Platform (using a method described in a later section to derive poverty estimates based on future GDP per capita).
- For market GNI we use the World Bank's Atlas measure.
- For military spending we use World Bank military spending as a percentage of GDP and for electricity consumption, we use World Bank electric power consumption kWh per capita.[40]
- For IMF Quota data and IBRD voting power we use the latest numbers from the organizations' respective websites.[41]
- We also use SSP forecasts of economic growth as part of our analysis of 'robustness' (although, to repeat, the SSPs use a notably different approach).[42]

3 Historical Regression Results

Our base regression is as follows:

$$\begin{aligned}(lnGDPPC_{t+10} - lnGDPPC_t) = \alpha(lnGDPPC_t) + \beta(under15pct_t) \\ +\gamma(over65pct_t) + \delta(tempover13_t) + \epsilon(lnyrsch_t) + C\end{aligned} \tag{1}$$

Where GDPPC is PPP GDP per capita, under15pct is proportion of the population under fifteen, over65pct is proportion of the population over 65, tempover13 is temperature above thirteen degrees centigrade and yrsch is years of education in the population aged 15-64.[43] As can be seen in table 2, all variables enter significantly with the expected sign. Table 3 suggests an interpretation of the coefficients. We find evidence of (conditional) convergence in the sense that that the coefficient on decade start log income is negative. Accounting for other variables, a 5 percentage point higher under-fifteen share in the population is associated with 7.9 percentage point lower income growth over the decade. A one degree higher average temperature over 13 degrees centigrade is associated with a 1.1 percentage point lower income growth over the decade.

[39] For countries with zero years of GDP data in the Penn World Tables but with data from the World Bank, World Bank data was used. These countries are Afghanistan, Kiribati, Kosovo, Libya, Marshall Islands, Micronesia, Fed. Sts., Nauru, Palau, Papua New Guinea, Puerto Rico, Samoa, San Marino, Solomon Islands, Somalia, Timor-Leste, Tonga, Tuvalu, and Vanuatu.

[40] (MS.MIL.XPND.GD.ZS, EG.USE.ELEC.KH.PC)

[41] For IMF voting power: https://www.imf.org/external/np/fin/quotas/2021/0730.htm. For IBRD voting power https://finances.worldbank.org/Shareholder-Equity/IBRD-Subscriptions-and-Voting-Power-of-Member-Coun/rcx4-r7xj/data

[42] Available here: https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about

[43] We use heteroskedasticity robust standard errors for our confidence intervals, note that a Breush-Pagan test did not report heteroskedasticity, while a White's test did.

Table 2: Core Regression

	(1)
	ln(GDP/Capita) - Lag10 ln(GDP/Capita)
Lag10 ln(GDPPC)	-0.160***
	(0.000)
Lag10 % of Pop under 15	-0.0159***
	(0.000)
Lag10 % of Pop over 65	-0.0151**
	(0.002)
Lag10 ln(Avg. Years of School)	0.115***
	(0.000)
Lag10 Deg. over 13C, RCP4.5	-0.0113**
	(0.001)
Constant	2.137***
	(0.000)
Observations	844
RMSE	0.358
R^2 adjusted	0.128

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Interpretations of changes in the base model parameters

Variable	Coefficient	Unit	Increase	% Change in (ln(GDP/C)-L10.ln(GDP/C))
L10.ln(GDP/Capita)	-0.1603	Ln(GDP/Capita)	1 Log point	-16.03
L10.% of Pop under 15	-0.01586	Percentage points	5%	-7.93
L10.% of Pop over 65	-0.01514	Percentage points	5%	-7.57
L10.ln(Avg. Years of School)	0.1152	Ln(Avg. Years of School)	1 Log point	11.52
L10.Deg. over 13C, RCP4.5	-0.01127	Degrees C	1 Degree	-1.13
Constant	2.137			

4 Central Forecast and Robustness

In order to generate a central forecast for 2030, we take our 2020 decadal data for input variables (income, education, fraction of population under age fifteen, fraction over age 65, temperature) and use coefficients from the core regression to generate a 2030 income estimate. We repeat the process with the forecast 2030 income and (independently) predicted 2030 values for education, age under fifteen and over 65 to generate a 2040 income estimate. The same process again gets us to a 2050 forecast for income.

For the central forecast, our demographic variables are from the UN medium variant population forecast. For temperature, we use RCP 4.5 forecasts. For our education variable, we create our own predicted values using prior education levels, the square and a constant

$$lnyrsch_{t+10} = \alpha \cdot lnyrsch_t + \beta \cdot lnyrsch_t^2 + C \tag{2}$$

Table 4 presents the results, which intriguingly implies average education reaches a maximum value of 13.25 years, a little below the maximum value in the historical data. This implies considerable educational convergence.

Table 4: Years of Schooling Regression

	Avg. Years of School
Lag10 Avg. Years of School	1.288***
	(0.000)
Lag10 (Avg. Years of School)^2	-0.0238***
	(0.000)
Constant	0.324***
	(0.000)
Observations	1084
R^2 adjusted	0.966

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In order to see how much data choices regarding forecast 'independent variables' drive our results, we use alternate population, education and temperature forecasts: the UN high and low variants (both for population share and total population), and the Wittgenstein medium variant for population and education which informed the SSPs (with the medium variant being used in SSP2). Table 5, covering major world countries, regions and income groups, suggests the forecasts are comparatively little influenced by our population forecast choices.

We also incorporate the potential impact of different temperatures out to 2050, using temperature forecasts associated with RCP 1.9 and 8.5—the most optimistic and pessimistic scenarios regarding concentrations of greenhouse gasses at century's end (associated with SSP1 and SSP5 respectively). With regard to temperature, the impact of milder or more severe climate change on output by 2050 again looks to be small. Three things are worth repeating, however: national analysis is an unsuitable aggregation level to uncover climate effects; this is only meant to incorporate

Table 5: GDP/Capita 2050, Population and Temperature Variants Robustness Checks

	KG	UN Low	UN High	Wittgenstein	RCP2.6	RCP8.5
Africa	8435	8920	8010	8944	8493	8313
China	32,266	35,161	31,848	33,962	32,496	31,759
DAC Members	63,952	68,140	61,909	63,183	64,238	63,372
EU Members	56,464	59,814	54,717	56,196	56,562	56,248
India	15,431	16,630	14,546	15,415	15,541	15,216
United States	75,571	81,068	72,976	74,448	76,168	74,389
Low income	4800	5024	4519	4854	4836	4729
Lower middle income	14,743	15,803	13,938	15,261	14,840	14,545
Upper middle income	32,760	35,587	31,890	33,938	32,951	32,325
High income	62,269	66,289	60,116	61,765	62,549	61,693
World	24,499	26,105	23,280	25,434	24,637	24,205

Table 6: GDP/Capita 2050, Regression Model Alternatives Robustness Checks

	KG	With Year	Country Fixed Effects
Africa	8435	8431	9428
China	32,266	26,799	24,561
DAC Members	63,952	50,381	88,850
EU Members	56,464	43,801	75,622
India	15,431	17,901	16,332
United States	75,571	60,160	93,365
Low income	4800	4724	4457
Lower middle income	14,743	15,915	16,117
Upper middle income	32,760	28,602	35,986
High income	62,269	50,725	93,531
World	24,499	22,377	30,119

the effect of temperature, not other climate impacts; and it is undoubted that the larger impacts are post-2050.[44]

We added a time variable (years after 1950) to the core regression and re-ran the forecasts with the coefficients that resulted (the regression results from this and the next robustness check are reported in Annex Table 26). These results suggest notably slow growth in richer countries (Table 6).

Finally, we add country dummies to our core regression and rerun forecasts using the revised coefficients including the dummies themselves. Our preferred approach 'locks in' regression to the mean in forecasts, which is to say that countries that have outperformed or underperformed historically compared to what would be expected given initial income, education, demographics and temperature are assumed to perform as expected given those variables in the future. But if fixed historical factors mean that certain countries will grow more slowly into the future, including country dummies will help to account for that. With country fixed effects, richer countries grow markedly *faster* than in our base forecast. It is worth noting that all robustness results fall within the range of our low and high variants reported in the next section.

5 Low and High Variants, Comparison with SSPs

In order to generate ranges for scenarios, for the positive forecast we take our 2020 decadal data for input variables (income, education, age under fifteen, age over 65, and temperature and coefficients from the base regression), then add to the predicted income value one half of the root mean squared error of the core regression. We repeat the process with the positive forecast 2030 income and predicted 2030 values for education, age under fifteen, age over 65, and temperature plus one half of the root MSE for 2040. The same process again gets us to a 2050 positive forecast for income. The same process only subtracting rather than adding one half of the root mean squared error provides values for 2030, 2040 and 2050 negative forecasts for each country.[45]

We compare results with OECD growth forecasts under SSPs. SSP 1 (Sustainability) involves low emissions and greater global equality; SSP 2 (Middle of the road) is closer to business as usual, SSP 3 (Regional rivalry) involves low economic development and little new clean technology; SSP 4 (Inequality) involves global divergence in both economic performance and environmental management; SSP 5 (Fossil-fueled development) is a high-growth, high-emissions scenario.

We need to harmonize SSP scenarios with our forecasts because the SSPs have GDP figures in 2005 PPP$ while we use 2017 PPP$, and a later start date. To do so, we use the GDP and GDP per capita growth rates implied by SSP scenarios for future years and apply them to our 2019 data to generate consistent, 2017 PPP growth forecasts for the SSP scenarios based on actual 2019 GDP and per capita GDP data expressed in 2017 PPP.

There is some debate over which associated concentration scenario is most likely in the literature, with the baseline emissions pathway most closely associated with SSP2 most likely and SSP5 least likely based on IEA energy projections while the baseline emissions pathway most closely associated

[44] Note also the costs of mitigation on a global scale are (also) small "the median annualized reduction in the growth rate of consumption [implied by the IPCC] is only 0.06 percentage points (0.04 to 0.14) compared with consumption that grows between 1.6% and 3% per year in the baseline https://www.nature.com/articles/s41558-021-01203-6

[45] Assuming normal distribution of errors, about 69 percent of errors are less than half an RMSE above the central estimate. This suggests the probability of being above one half the RMSE above the central estimate three times over is about 3% (although given a normal distribution this should not be taken to imply the probability of achieving an income above that value in 2050 is so low for any particular country).

with SSP5 the most likely based on historical emissions. But it is worth noting in neither case was the plausibility based on a discussion of the economic forecasts of the SSPs themselves, about which there has been little apparent discussion.[46]

It is important to note that while our low and high variants share underlying population forecasts taken from the UN Medium Variant, different SSPs suggest markedly different rates of population growth, from considerably below the UN Low Variant in SSP1 (8.5 billion) to 1.5 billion (18 percent) more than that in SSP3, involving 200 million *fewer* people in OECD DAC countries and 1.7 billion *more* people in developing countries (See Table 7). Clearly this will generate considerable differences in total GDP forecasts when combined with GDP per capita numbers.

Table 7: 2050 Populations in Billions, UN and SSP

	UN Medium	UN Low	UN High	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	2.49	2.29	2.69	1.77	2.02	2.35	2.27	1.74
China	1.40	1.22	1.41	1.22	1.26	1.31	1.18	1.22
DAC Members	1.10	1.01	1.17	1.21	1.17	0.99	1.11	1.37
EU Members	0.42	0.39	0.45	0.48	0.47	0.40	0.44	0.54
India	1.64	1.53	1.82	1.55	1.73	1.97	1.60	1.55
United States	0.38	0.35	0.40	0.41	0.40	0.33	0.38	0.48
Low income	1.32	1.26	1.48	0.93	1.09	1.28	1.27	0.91
Lower middle income	4.46	4.11	4.87	3.75	4.18	4.79	4.18	3.69
Upper middle income	2.64	2.34	2.74	2.34	2.47	2.65	2.34	2.34
High income	1.28	1.18	1.37	1.40	1.38	1.19	1.31	1.58
World	9.73	8.93	10.51	8.46	9.17	9.96	9.14	8.56

Our central forecast for GDP per capita in the World is around $25,000. This compares to an average of $29,000 for the SSPs. Our range is $16-39,000, the range for SSPs is $18-42,000 (note current GDP per capita is around $16,000). This suggests our forecast is slightly more pessimistic than the average for SSPs, but broadly similar in terms of the likely range of plausible outcomes.

Our central forecast shares with SSP scenarios the prediction of a notable growth slowdown in rich countries over the next thirty years (Table 8). For the US, our central estimate equates to an annualized real GDP per capita growth rate of about 0.6 percent, about half the rate over the past two decades, with the optimistic scenario a little above two percent growth. Looking at individual countries and regions, perhaps the most notable difference between our exercise and the SSPs regards China, where SSPs suggest higher per capita growth over the next thirty years (just above an average annual rate of four percent) than our central estimate (a little below three percent, see Figure 1). Also notable is that our upside estimates for the (per capita) economic performance of richer countries are considerably more bullish than any of the SSPs (where the *maximum* growth rate for the US translates into a 0.7 percent growth rate).

Looking at GDP forecasts (Table 9), comparing the outlier SSP scenarios (3 and 5) with our central estimates and low/high ranges, SSP3 is approximately at the level of our low-range outcome (in which every country worldwide underperforms on growth in all three decades 2020-50 by half of

[46] SSP5 is (should be?) associated with RCP8.5 and SSP4 with RCP 6.0 Hausfather, Zeke; Peters, Glen P. (2020-01-29). "Emissions – the 'business as usual' story is misleading". Nature. 577 (618–620). doi:10.1038/d41586-020-00177-3. Schwalm, Christopher R.; Glendon, Spencer; Duffy, Philip B. (2020-08-03). "RCP8.5 tracks cumulative CO2 emissions". PNAS. 117 (33): 19656–19657. doi:10.1073/pnas.2007117117

Table 8: GDP/Capita 2050 Forecasts for major entities, Central, Positive, and Negative, and SSPs

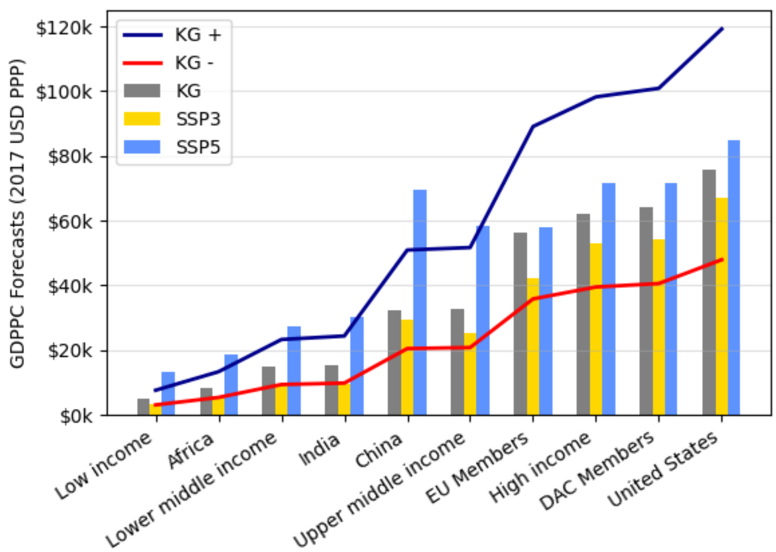
	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	4801	8435	13,306	5347	14,594	9496	5861	5943	18,827
China	13,988	32,266	50,897	20,455	55,893	40,350	29,410	42,734	69,549
DAC Members	50,654	63,952	100,879	40,542	62,381	57,406	54,282	64,516	71,423
EU Members	43,951	56,464	89,068	35,795	50,492	47,349	42,176	51,202	57,939
India	6547	15,431	24,341	9782	23,798	15,883	9587	14,890	30,057
United States	63,393	75,571	119,207	47,908	75,434	67,814	67,236	77,664	84,741
Low income	1940	4800	7572	3043	9814	5677	3327	2828	13,044
Lower middle income	7012	14,743	23,256	9346	21,271	14,347	9016	11,859	27,168
Upper middle income	16,036	32,760	51,677	20,768	46,776	34,724	25,331	35,832	58,236
High income	48,913	62,269	98,224	39,475	61,828	56,703	52,786	63,315	71,599
World	16,176	24,499	38,645	15,531	33,814	25,227	17,925	24,171	42,392

Table 9: GDP 2050 Forecasts (in trillions) for major entities, Central, Positive, and Negative, and SSPs

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	6.28	21.00	33.12	13.31	25.80	19.18	13.77	13.48	32.77
China	20.06	45.25	71.38	28.69	68.44	50.97	38.45	50.57	85.16
DAC Members	53.86	70.23	110.78	44.52	75.23	67.25	53.54	71.33	97.79
EU Members	19.56	23.87	37.65	15.13	24.28	22.13	17.02	22.64	31.04
India	8.95	25.29	39.90	16.03	36.90	27.54	18.89	23.84	46.50
United States	20.86	28.67	45.23	18.18	31.01	27.28	22.47	29.45	40.31
Low income	1.29	6.32	9.97	4.00	9.14	6.20	4.27	3.60	11.93
Lower middle income	22.95	65.68	103.61	41.64	79.78	60.03	43.17	49.51	100.35
Upper middle income	40.26	86.39	136.28	54.77	109.55	85.94	67.14	83.87	136.04
High income	60.24	79.98	126.17	50.71	86.63	78.14	62.72	82.92	113.18
World	124.75	238.46	376.15	151.17	286.16	231.34	178.52	220.84	363.01

the RMSE). It predicts a world economy of $179 trillion in 2050 compared to our low-end estimate of $152 trillion. SSP5, at $363 trillion, is more optimistic than our central estimate ($239 trillion), but below our high estimate ($377 trillion). The average across five SSP scenarios is $256 trillion, or about seven percent higher than our central estimate. This suggests that, broadly, our approach and the SSP scenarios agree on the plausible range of outcomes for the world economy in 2050 (Figure 2).

Figure 1: GDP/Capita PPP in 2050: KG & SSP (in thousands of $)



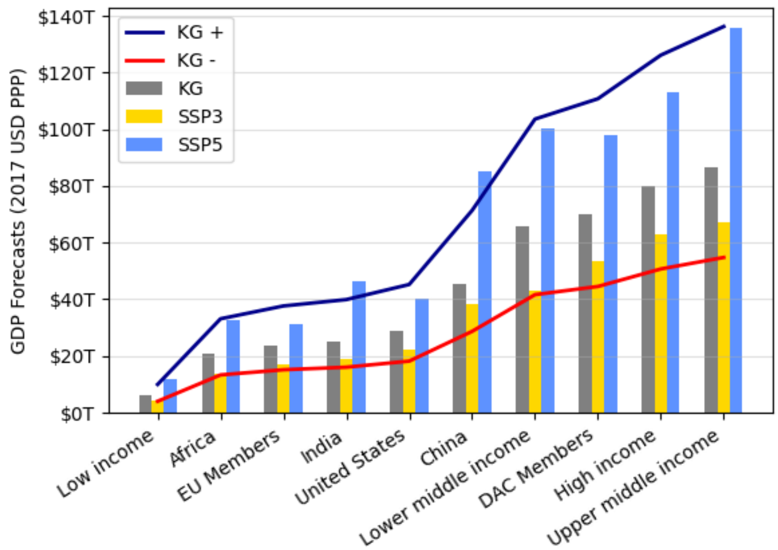
6 Poverty Forecasts

We use the Stata functions embedded in the World Bank's Poverty and Inequality Platform to predict 2050 poverty at various lines under our scenarios assuming within-country inequality remains the same over that time and consumption growth equals GDP per Capita growth.[47] Our approach is to estimate $2.15 poverty by calculating poverty in 2020 (or nearest year) using a line equal to ($2.15/(2050 GDP per Capita/2020 GDP per Capita). This produces the same result as forecasting incomes using the current consumption distribution and multiplying it by the 2020-2050 growth rate but sidesteps the issue that the World Bank only publishes decile data for current income distributions. Combined with UN population forecasts, we create aggregate shares.

A note: for much of the Americas, the data on poverty is based on an income rather than a consumption measure. Incomes are often considerably below consumption at the bottom of the

[47]See Dollar, D., & Kraay, A. (2002). Growth is Good for the Poor. Journal of economic growth, 7(3), 195-225.

Figure 2: GDP PPP in 2050: KG & SSP (in trillions of $)



income scale, leading to relatively higher poverty numbers.[48]

Table 10 presents data on the extreme poverty line of $2.15 a day. Under the base forecast, the proportion in extreme poverty worldwide falls below 2 percent in 2050 and from 29 to 7 percent on the continent of Africa (again note the US number is for income and not consumption, and appears to reflect censored data). Under the optimistic forecast for Africa (associated with a 3.5 percent growth rate between now and 2050), extreme poverty as currently measured falls below 2 percent.

We repeat the exercise for $10/day poverty (Table 11. In 2019, about 57 percent of the world lived on less than $10/day (2017 $PPP). This included nearly nine out of ten people in the continent of Africa and India. In the positive growth scenario, this could drop as low as one in five of the World, one in five people in India and less than one half of Africa's population. The central forecast suggests nearly two thirds of the world will live on more than $10 a day by 2050, along with nearly half of the Indian population and thirty percent of those in Africa.

7 Scenarios

We use high/low country forecasts to create three sets of 2050 scenarios for outcomes based on top and bottom tail performance for (i) All African countries; (ii) Brazil, China, India; (iii) All DAC countries (other countries remain at the central forecast).

Note that economies are connected to each other, so that slow growth in the rest of the world

[48]See a discussion here: https://www.cgdev.org/blog/chart-week-4-angus-deaton-location-poverty. Note also our data for Argentina (reflecting what is available on the Word Bank platform) is only for urban poverty.

Table 10: Percent of People under $2.15/Day, 2050 Forecasts

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	29.23	7.00	1.90	19.75	1.92	5.68	18.33	24.43	0.97
China	0.14	0.01	0.00	0.03	0.00	0.01	0.01	0.00	0.00
DAC Members	0.59	0.57	0.39	0.65	0.52	0.56	0.60	0.53	0.52
EU Members	0.46	0.32	0.25	0.47	0.35	0.43	0.53	0.39	0.32
India	9.47	0.15	0.02	1.56	0.02	0.13	1.72	0.19	0.00
United States	1.00	1.00	0.75	1.00	1.00	1.00	1.00	1.00	1.00
Low income	38.21	6.89	1.94	20.10	2.07	5.89	18.93	26.10	1.09
Lower middle income	10.16	1.99	0.50	6.18	0.42	1.38	5.78	7.12	0.20
Upper middle income	1.48	0.40	0.14	1.02	0.29	0.53	1.08	0.63	0.18
High income	0.56	0.51	0.35	0.61	0.47	0.51	0.57	0.48	0.47
World	8.18	2.02	0.58	5.90	0.57	1.55	5.58	7.12	0.34

Table 11: Percent of People under $10/Day, 2050 Forecasts

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	88.63	70.64	49.12	85.07	39.63	66.09	84.62	85.19	25.87
China	45.84	6.68	0.57	24.63	0.33	2.28	9.44	1.64	0.11
DAC Members	2.58	1.59	0.92	3.23	1.77	1.99	2.31	1.72	1.42
EU Members	4.24	1.78	0.93	4.58	2.44	3.02	4.40	2.66	1.77
India	91.73	55.64	20.48	81.98	21.93	53.35	82.68	58.37	9.97
United States	2.25	2.00	1.25	3.25	2.00	2.25	2.25	2.00	1.75
Low income	84.95	70.22	49.86	82.77	36.71	65.72	82.46	85.37	22.88
Lower middle income	84.63	52.77	25.48	75.05	28.31	55.05	78.21	66.94	15.78
Upper middle income	41.84	10.85	3.51	27.95	6.47	11.32	20.96	11.22	4.12
High income	3.04	1.69	0.94	3.54	1.80	2.14	2.81	1.86	1.42
World	57.36	36.81	19.48	53.58	18.67	36.32	54.15	45.62	10.64

Table 12: GDP shares (in percent) under different regional scenarios

		Base	Africa Stagnates		Africa Roars	
		Forecast	DAC Stagnates	DAC Roars	DAC Stagnates	DAC Roars
BRIC Roars	Africa	8.81	5.33	4.22	12.30	9.87
	Brazil	2.70	4.08	3.22	3.78	3.03
	China	18.98	28.61	22.60	26.50	21.27
	DAC	29.45	17.84	35.08	16.53	33.01
	EU	10.01	6.29	11.65	5.82	10.96
	India	10.61	15.99	12.63	14.81	11.89
	United States	12.02	7.28	14.32	6.75	13.48
BRIC Stagnates	Africa	8.81	7.53	5.47	16.84	12.60
	Brazil	2.70	2.31	1.68	2.08	1.55
	China	18.98	16.22	11.80	14.58	10.91
	DAC	29.45	25.17	45.56	22.64	42.13
	EU	10.01	8.87	15.12	7.97	13.99
	India	10.61	9.07	6.59	8.15	6.10
	United States	12.02	10.28	18.60	9.24	17.20

(and especially among trading partners) is associated with slower growth at home.[49] These scenarios are therefore unlikely: it is improbable that Africa could see very rapid growth even as the rest of the world is seeing very slow growth, for example. But they can still help set boundaries between more and less probable outcomes for the shape of the global economy in 2050.

Table 12 suggests the wide range of (at least somewhat) plausible outcomes for the shape of the world economy in 2050. If the BRICs outperform while DAC countries and Africa underperform, China would account for 29 percent of the World economy in 2050 compared to 7 percent for the US and 6 percent for the EU. If DAC countries outperform while the BRICs and Africa underperform, China would account for 12 percent of the world economy, while DAC countries would account for a slightly larger percentage of the World economy in 2050 than today (though note it is only in this extreme case that they do *not* become relatively smaller). The US will have a global share of the economy between 6.7 percent and 18.6 percent again suggesting the very best outcome it could reasonably hope for is maintaining its share of the global economy with the likely forecast being a reduced dominance, in the worst case to about a third of its current share. It will only regain a larger GDP PPP share than China if it significantly over-performs and/or China significantly under-performs. Similarly, even in the most optimistic of scenarios in terms of relative dominance, the EU at best stays still with a worst case being a 5.8 percent share of the global economy.

[49] Arora, V., & Vamvakidis, A. The Impact of US Economic Growth on the Rest of the World: How Much Does It Matter?. Arora, Vivek, and Athanasios Vamvakidis. "How much do trading partners matter for economic growth?." IMF staff papers 52.1 (2005): 24-40.

8 Market Outcomes

Up until this point we have been using PPP measures. Many outcomes of interest are better (or equally) examined using market rate exchange rates. It would be possible to run the base regression using GDP per capita as measured at market rates, take the resulting coefficients alongside the root mean square error and use these to forecast scenarios for market GDP per capita into the future. However, this might drive a considerable wedge between the world of PPP scenarios and those of market scenarios. Instead, we use 2020 Atlas GNI and apply the growth rates from our 2020-2050 PPP model to predict 2050 Atlas GNI (Table 13. (Note this may create some bias: the relationship between GNI per capita PPP and GNI per capita at market rates is not linear: poorer countries tend to have PPP GNI per capita that is considerably higher than market GNI per capita, the gap between the two declines at higher incomes.)

The forecasts suggest that in terms of the market GDP shares, current high income countries will fall from accounting for 63 percent to a little under 50 percent. China alone may account for as much as a fifth of global market GDP—a little more than the US. The EU's share may drop from 18 percent to 13 percent (Table 14).

Table 13: GNI Atlas/Capita 2050 Forecasts, Central, Positive, and Negative, and SSPs

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	1843	3287	5185	2084	5715	3700	2275	2292	7386
China	10,122	23,348	36,830	14,801	40,445	29,198	21,281	30,922	50,327
DAC Members	48,670	61,432	96,904	38,944	60,208	55,276	52,376	62,307	69,032
EU Members	36,184	45,922	72,439	29,112	41,388	38,925	34,669	42,142	47,605
India	2104	4959	7822	3143	7648	5104	3081	4785	9659
United States	65,821	78,465	123,773	49,743	78,323	70,411	69,812	80,639	87,987
Low income	652	1641	2588	1040	3391	1906	1086	917	4541
Lower middle income	2429	5126	8085	3249	7449	5004	3146	4060	9518
Upper middle income	9479	19,690	31,060	12,482	29,413	21,509	15,539	22,273	36,611
High income	45,144	57,048	89,989	36,165	56,198	51,206	47,580	57,272	65,036
World	11,383	15,431	24,341	9782	21,118	16,009	11,465	15,898	26,583

Current cutoffs of LIC/LMIC/UMIC/HIC are \$1,085 or less in 2021; lower middle-income economies are those with a GNI per capita between \$1,086 and \$4,255; upper middle-income economies are those with a GNI per capita between \$4,256 and \$13,205; high-income economies are those with a GNI per capita of \$13,205 or more. Using those same cutoffs and our forecast market GNI, we examine how much of the world population would be in each income category in 2050. Less than one percent of the World's population lives in a low income country in 2050 under our baseline scenario, that falls to zero under the optimistic scenario. The global share of population living in a high income country doubles even under a pessimistic scenario, not least because Brazil and China are already close to the cutoff (Table 15).

Table 14: GNI Atlas 2050 Forecasts (in trillions), Central, Positive, and Negative, and SSPs

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	2.41	8.18	12.91	5.19	10.11	7.47	5.34	5.20	12.86
China	14.51	32.74	51.65	20.76	49.53	36.88	27.82	36.60	61.63
DAC Members	51.75	67.46	106.42	42.77	72.61	64.75	51.66	68.88	94.51
EU Members	16.10	19.41	30.62	12.31	19.90	18.20	13.99	18.63	25.50
India	2.87	8.13	12.82	5.15	11.86	8.85	6.07	7.66	14.94
United States	21.66	29.77	46.96	18.87	32.20	28.33	23.33	30.57	41.86
Low income	0.43	2.16	3.41	1.37	3.16	2.08	1.39	1.17	4.15
Lower middle income	7.95	22.84	36.02	14.48	27.94	20.94	15.07	16.95	35.16
Upper middle income	23.80	51.92	81.91	32.92	68.88	53.23	41.19	52.13	85.52
High income	55.60	73.28	115.59	46.45	78.74	70.56	56.54	75.01	102.80
World	87.78	150.20	236.93	95.22	178.72	146.81	114.19	145.26	227.64

Table 15: Population (%) in Country Income Level Groups (2021 GNI Atlas/Capita Cut-offs)

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
LIC	7.91	0.95	0.00	6.44	0.16	1.01	7.72	12.12	0.13
LMIC	42.00	24.94	15.25	43.77	14.76	23.75	46.74	22.00	4.10
UMIC	34.44	36.39	42.81	22.04	42.13	37.28	18.42	30.71	46.46
HIC	15.65	37.72	41.93	27.75	42.95	37.96	27.11	35.16	49.31

9 Impact on International Financial Institutions

IMF quota shares and new issuances are (currently) guided by a formula containing number of variables including market and PPP GDP, openness, reserves and a measure of volatility.[50] The formula is only a guide, however, with actual new quota issuances the result of negotiations that need to be approved with an 85% percent majority. Compared to the formula, quota shares are currently biased toward OECD countries. The US quota share should drop from its current 17.4 percent to 14.8 percent and China's should climb from 6.4 to 14.1 percent.[51]

To provide scenarios for 2050 quota share, we first run a regression with the dependent variable *formula* quotas using the IMF's current formula against our 2019 GDP (PPP) and GDP per capita (PPP) values.[52]

$$\text{IMF formula quota} = \alpha(GDP) + \beta(GDPPC) + C \tag{3}$$

Table 16: IMF Quotas Regression

	(1) Quotas (Current Formula)
GDP	0.00324***
	(0.000)
GDPPC	42994.1***
	(0.000)
Constant	-477663826.5**
	(0.002)
Observations	187
R^2 adjusted	0.964

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We then use our forecast 2050 GDP and GDP per Capita numbers to calculate two 2050 quota scenarios for 2050, first ('Method 1') on the assumption that total new quota allocations take place in line with growth of GDP and GDP per capita according to our regression coefficients but that (only) new quota allocations follow the predicted quota formula so that 2050 quotas equal:

$$= \alpha(GDP_{2050} - GDP_{2020}) + \beta(GDPPC_{2050} - GDPPC_{2020}) + \text{Actual Quota}_{2020} \tag{4}$$

Second ('Method 2') on the assumption that total new quota allocations take place in line with growth of GDP and GDP per capita according to our regression coefficients and the IMF moves fully toward quota distribution according to the formula such that 2050 quotas equal:

$$= \alpha(GDP_{2050}) + \beta(GDPPC_{2050}) + C \tag{5}$$

[50] https://www.imf.org/en/Publications/Policy-Papers/Issues/2016/12/31/Quota-Formula-Data-Update-PP4967
[51] https://www.imf.org/external/np/fin/quotas/2022/0728.htm
[52] https://www.imf.org/external/np/fin/quotas/2022/0728.htm

There are a number of reasons to think outcomes might be different from this forecast beyond the considerable issue of uncertainty in forecast growth. Not least, our estimate of gross quota allocation could be an underestimate as IMF staff suggest that the Fund is currently considerably undersized compared to its historical scale relative to the global economy.[53] On the other hand, it might be an overestimate if the political difficulty of getting 85 percent agreement among shareholders blocks increases. With these caveats, the results presented in Tables 17 and 18 suggest a considerable swing in IMF voting power away from current high-income countries towards the global South. Notably, the US would lose its veto power under either scenario and China would gain veto power if the IMF moves fully toward quota distribution according to the current formula (under existing rules, this also suggests the IMF headquarters would be moved to Beijing).[54]

Politically, it may be hard to imagine the US voluntarily surrendering its veto power. Under those circumstances, setting the US share under both scenarios to 15.1 percent but otherwise following the same method as above, China would still (just) achieve veto power itself in 2050 under a scenario of (otherwise) moving fully toward quota distribution according to the current formula. Table 19 suggests quota shares under different regional growth scenarios and method 1. Under any reasonable growth scenario, assuming the IMF does not move away from a formual-based approach, DAC countries will see reduced voting power.

Table 17: IMF Quotas in Billions of SDRs, 2019 and 2050 Projections

	2019	2050 (method 1)	2050 (method 2)	2050 (method 3)	2050 (method 4)
Africa	24.8	59.3	66.5	57.8	62.9
China	30.5	112.3	147.3	109.3	139.5
DAC Members	291.1	346.6	293.7	359.6	327.4
EU Members	124.7	142.1	133.7	138.4	126.6
India	13.1	65.9	82.0	64.2	77.7
United States	83.0	108.2	95.5	127.5	139.8
Low income	7.4	14.6	13.8	14.2	13.0
Lower middle income	47.3	180.4	220.4	175.7	208.7
Upper middle income	97.3	253.2	314.8	246.5	298.0
High income	320.6	392.6	376.9	404.4	406.2
World	476.3	844.3	925.8	844.3	925.8

World Bank (IBRD) voting power is the result of a formula that weights 48 percent market GDP, 32 percent PPP GDP and 20 percent contributions to IDA, the World Bank's soft lending arm along with a 0.95 'compression factor' to reduce shareholding differences between smallest and largest members.[55] Given future IDA contributions are unknown, we follow a forecasting strategy that predicts votes based on the coefficients from a regression on current votes below (see Table 20):

[53]https://www.imf.org/en/Publications/Policy-Papers/Issues/2020/02/13/Fifteenth-and-Sixteenth-General-Reviews-of-Quotas-Report-of-the-Executive-Board-to-the-Board-49049?sc_mode=1

[54]See the discussion in Subramanian, A. (2011). Eclipse: Living in the shadow of China's economic dominance. Peterson Institute.

[55]https://www.devcommittee.org/sites/dc/files/download/Documents/2020-09/Final20DC2020-000920Shareholding.pdf

Table 18: IMF Quota Shares in Percent, 2019 and 2050 Projections

	% 2019	% 2050 (method 1)	% 2050 (method 2)	% 2050 (method 3)	% 2050 (method 4)
Africa	5.2	7.0	7.2	6.8	6.8
China	6.4	13.3	15.9	13.0	15.1
DAC Members	61.1	41.0	31.7	42.6	35.4
EU Members	26.2	16.8	14.4	16.4	13.7
India	2.8	7.8	8.9	7.6	8.4
United States	17.4	12.8	10.3	15.1	15.1
Low income	1.6	1.7	1.5	1.7	1.4
Lower middle income	9.9	21.4	23.8	20.8	22.5
Upper middle income	20.4	30.0	34.0	29.2	32.2
High income	67.3	46.5	40.7	47.9	43.9
World	100.0	100.0	100.0	100.0	100.0

Table 19: IMF Quota shares (in percent) (method 1) under different regional scenarios

		Base	Africa Stagnates		Africa Roars	
		Forecast	DAC Stagnates	DAC Roars	DAC Stagnates	DAC Roars
BRIC Roars	Africa	7.03	3.13	2.33	11.97	9.12
	Brazil	2.61	4.11	3.06	3.74	2.85
	China	13.30	23.40	17.41	21.26	16.20
	DAC Members	41.05	27.71	46.19	25.18	42.98
	EU Members	16.83	11.45	18.84	10.40	17.53
	India	7.80	13.44	10.00	12.22	9.31
	United States	12.82	8.66	14.43	7.87	13.42
BRIC Stagnates	Africa	7.03	4.37	2.95	16.10	11.34
	Brazil	2.61	2.30	1.55	2.01	1.42
	China	13.30	9.59	6.49	8.42	5.93
	DAC Members	41.05	38.58	58.46	33.85	53.41
	EU Members	16.83	15.94	23.84	13.98	21.78
	India	7.80	5.89	3.98	5.16	3.64
	United States	12.82	12.05	18.26	10.58	16.68

$$\text{IBRD votes} = \alpha(GDP) + \beta(GDPPC) + C \tag{6}$$

As with the IMF results, the results for the World Bank suggest a sharp decline for EU and US voting shares and a loss of veto power over major decisions for the US (Table 21). The likelihood that China would gain veto power looks somewhat lower, however. And, as with IMF quota shares, political realities might delay or prevent the loss of the US veto.

Table 20: IBRD Votes Regression

	(1) IBRD Votes
GDP	1.47e-08***
	(0.000)
GDPPC	0.288***
	(0.000)
Constant	-967.0
	(0.612)
Observations	187
R^2 adjusted	0.782

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 21: IBRD Vote Shares in Percent, 2019 and 2050 Projections

	2019	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	7.3	8.3	8.6	7.9	10.1	8.7	7.4	6.2	10.3
China	5.7	13.7	13.6	14.0	17.6	16.1	15.6	16.5	17.3
DAC Members	56.5	31.5	31.3	31.7	26.8	30.0	32.1	33.2	26.7
EU Members	22.9	16.1	16.1	16.1	12.5	14.3	15.2	15.4	12.1
India	3.0	7.7	7.6	7.8	9.4	8.6	7.6	7.7	9.4
United States	15.5	9.0	8.9	9.2	8.2	8.9	9.5	9.9	8.4
Low income	2.3	2.1	2.3	1.9	3.2	2.3	1.7	1.1	3.4
Lower middle income	12.9	22.8	22.9	22.7	24.6	22.2	19.8	18.5	24.8
Upper middle income	20.8	32.6	32.5	32.7	34.6	33.2	32.8	33.6	34.1
High income	63.2	42.5	42.4	42.7	37.3	41.8	45.0	46.4	37.3
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 22: IBRD Vote shares (in percent) under different regional scenarios

		Base	Africa Stagnates		Africa Roars	
		Forecast	DAC Stagnates	DAC Roars	DAC Stagnates	DAC Roars
BRIC Roars	Africa	8.33	5.01	3.83	12.78	9.97
	Brazil	2.08	3.34	2.56	3.07	2.39
	China	13.74	22.02	16.85	20.22	15.77
	DAC Members	31.48	20.06	38.85	18.42	36.37
	EU Members	16.12	11.25	18.72	10.33	17.52
	India	7.66	12.28	9.39	11.27	8.79
	United States	9.02	5.80	11.07	5.33	10.36
BRIC Stagnates	Africa	8.33	6.46	4.63	16.12	11.89
	Brazil	2.08	1.72	1.23	1.54	1.14
	China	13.74	11.41	8.17	10.23	7.55
	DAC Members	31.48	25.90	46.94	23.23	43.37
	EU Members	16.12	14.52	22.62	13.02	20.90
	India	7.66	6.36	4.55	5.70	4.20
	United States	9.02	7.49	13.37	6.72	12.36

10 Impact on Energy Consumption and Military Spending

We also forecast electricity consumption, based on the historical relationship between income per capita and consumption, which appears to remain relatively stable over time (see Table 24).[56]

$$Ln(KWh/Capita) = \alpha(lnGDPPC) + \beta(lnGDPPC)^2 + C \tag{7}$$

Our central forecast suggests world electricity consumption of 42.2 trillion kilowatt-hours in 2050, up from 21.8 trillion in 2014 (Table 24). This is effectively the same as a forecast by the US Energy Information Administration that world electricity generation will be 42.0 trillion kilowatt-hours in 2050[57]. The share of (current) high income countries in global electricity consumption under the central forecast will fall from 48 percent to 32 percent. Current low income countries will still be responsible for less than five percent of consumption in 2050 even if they considerably outperform growth expectations and the rest of the world under-performs. The central forecast is that they will be responsible for two percent of global consumption.

Based on current shares of military spending as a percentage of GDP, we examine the potential range of proportions of global spending in 2050 under different Atlas GDP growth scenarios (Table 25). The central forecast is for the US to remain the largest military in terms of spending in 2050, although its share of global spending will fall from about one quarter to about one fifth. At the same time it is quite plausible to imagine both India and China outspending the US on defense in 2050. (Note, these scenarios do not account for the fact that higher military spending is often associated with slower growth).

[56] Moss, T et al (2021) The Modern Energy Minimum: The case for a new global electricity consumption threshold
[57] https://www.eia.gov/outlooks/ieo/

Table 23: Ln(Electricity Consumption per Capita) Regression

	(1) ln(Electricity Consumption/Capita)
ln(GDPPC)	3.385***
	(0.000)
ln(GDP/Capita)^2	-0.118***
	(0.000)
Constant	-13.74***
	(0.000)
Observations	5596
RMSE	0.789
R^2 adjusted	0.778

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 24: Electricity Consumption 2050, Trillions of Kilowatt-hours

	2014	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	0.64	3.47	5.80	1.99	4.63	3.24	2.11	2.09	5.99
China	5.47	8.45	12.64	5.37	11.92	9.33	7.21	9.20	14.15
DAC Members	9.57	11.81	16.42	8.10	12.72	11.58	9.29	11.97	16.03
EU Members	2.66	4.13	5.82	2.79	4.29	3.94	3.08	3.98	5.35
India	1.04	4.63	7.51	2.72	6.94	5.06	3.20	4.35	8.72
United States	4.14	4.66	6.37	3.25	5.05	4.56	3.76	4.76	6.36
Low income	0.09	0.90	1.61	0.48	1.55	0.92	0.53	0.42	2.12
Lower middle income	2.46	11.89	19.18	7.03	14.84	10.85	7.23	8.74	18.66
Upper middle income	8.67	16.00	23.85	10.22	19.44	15.82	12.54	15.35	23.22
High income	10.45	13.42	18.65	9.20	14.65	13.44	10.89	13.92	18.50
World	21.76	42.22	63.32	26.94	50.69	41.24	31.42	38.60	62.78

Table 25: Military Spending 2050 (in Billions)

	2020	KG	KG +	KG -	SSP1	SSP2	SSP3	SSP4	SSP5
Africa	130	397	626	252	452	356	272	279	563
China	351	791	1248	502	1198	892	673	885	1490
DAC Members	1317	1766	2786	1120	1910	1700	1369	1811	2478
EU Members	313	384	605	243	399	361	279	371	508
India	258	729	1150	462	1064	794	545	687	1340
United States	780	1072	1691	679	1160	1021	841	1102	1508
Low income	21	103	162	65	164	117	84	72	211
Lower middle income	528	1527	2409	968	1812	1379	989	1163	2272
Upper middle income	813	1712	2700	1085	2086	1655	1312	1634	2617
High income	1611	2220	3501	1407	2358	2124	1750	2299	3099
World	2974	5563	8776	3527	6444	5300	4162	5189	8234

11 Conclusion

There is considerable uncertainty about the future shape of the world economy and it is no challenge to think of events that could leave it looking far different from any of the scenarios we have presented. Even within the scenarios, the range of plausible outcomes is large enough to suggest current global income convergence could dramatically accelerate or it could reverse, for example. The impact of policy change at the national and global level could be very large: a retreat from globalization might cost trillions in world output, the global embrace of considerably more free movement of labor could add trillions. That said, some conclusions look to be reasonably robust at least across the range of scenarios:

- Demographic change will be an increasing drag on growth particularly in richer (upper middle and high income) countries. Education is likely to be a factor favoring convergence globally. And while climate change (at least as reflected in temperature, at the national level) will be a force for slower growth especially in poorer countries it is unlikely to be a major driver of global economic trends up to 2050.

- The share of OECD DAC countries in the global economy is very likely to shrink. This reflects the likelihood of (i) relatively slower per capita income growth (both compared to the past and to poorer countries); and (ii) stalling or declining population compared to continued population growth in most low and middle income countries.

- It is plausible to imagine that \$2.15 a day poverty will have effectively disappeared by 2050 (which would be good news, if two decades later than envisaged by the UN Sustainable Development Goals). It is also plausible that more than two thirds of the world will be living on more than \$10 a day (up from about 42 percent today). Low income countries may disappear as a group, and the proportion of the world living in high income countries is very likely to more than double from its current proportion of 16 percent.

- The shrinking share of the US in the global economy suggests an end to the country's veto power in both IMF and World Bank decision making processes unless the institutions move even further away from a voting/shareholding formula based on relative economic size.

- Global electricity consumption can be reasonably expected to double by 2050, with high income countries seeing slower growth but current low income countries still responsible for less than five percent of consumption (more likely two percent).
- The US is likely to remain the largest military in terms of spending in 2050, but is global lead will considerably diminish and it is plausible to imagine both India and China outspending the US on defense in 2050.

For all of the challenges this likely future may present, it is one of a richer planet with more resources to respond to threat from pandemics through climate shocks, containing many fewer people living in the kind of absolute poverty that was the lot of ninety percent of humankind for nearly all of our history.

A Appendix

Table 26: Robustness check regressions, on $(ln(gdppc)_t - ln(gdppc)_{t-10})$

	(1) Base model	(2) With Year	(3) Country FEs
Lag10 ln(GDPPC)	-0.160***	-0.170***	-0.518***
	(0.000)	(0.000)	(0.000)
Lag10 % of Pop under 15	-0.0159***	-0.0181***	-0.0242***
	(0.000)	(0.000)	(0.000)
Lag10 % of Pop over 65	-0.0151**	-0.0168**	0.0167
	(0.002)	(0.001)	(0.072)
Lag10 ln(Avg. Years of School)	0.115***	0.146***	0.197***
	(0.000)	(0.000)	(0.000)
Lag10 Deg. over 13C, RCP4.5	-0.0113**	-0.00829*	-0.0182*
	(0.001)	(0.019)	(0.017)
Year (base 1950)		-0.00249**	
		(0.001)	
Constant	2.137***	2.362***	5.246***
	(0.000)	(0.000)	(0.000)
Observations	844	844	843
RMSE	0.358	0.357	0.329
R^2 adjusted	0.128	0.133	0.267

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 27: Exploratory regressions, on $(ln(GDPPC)_t - ln(GDPPC)_{t-10})$

	(1)	(2)	(3)	(4)	(5)	(6)
L10.ln(GDPPC)	-0.156***	-0.167***	-0.156***	-0.162***	-0.155***	-0.112***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L10.% of Pop under 15	-0.0171***	-0.0184***	-0.0178***	-0.0170***	-0.0153***	-0.0144***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L10.% of Pop over 65	-0.00248	-0.00712	-0.0104	-0.00833	0.0203	0.0935**
	(0.666)	(0.200)	(0.062)	(0.145)	(0.153)	(0.005)
L10.Avg. Years of School	0.0859***	0.0968***	0.0910***			
	(0.000)	(0.000)	(0.000)			
L10.(Avg. Years of School)^2	-0.00570***	-0.00566***	-0.00541***			
	(0.000)	(0.000)	(0.000)			
Year (base 1950)		-0.00283***	-0.00244*			
		(0.001)	(0.013)			
L10.Gravity/GDPPC			0.00180			
			(0.698)			
Deg. over 13C, RCP4.5			-0.00537			
			(0.164)			
L10.ln(Avg. Years of School)				0.113***	0.103***	0.102***
				(0.000)	(0.000)	(0.000)
L10.(% of Pop over 65)^2					-0.00143*	
					(0.016)	
L10.Over 65 % * ln(GDPPC)						-0.00979**
						(0.002)
Constant	1.930***	2.168***	2.105***	2.078***	1.885***	1.504***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	844	844	835	844	844	844
RMSE	0.361	0.359	0.360	0.362	0.361	0.361
R^2 adjusted	0.116	0.125	0.125	0.111	0.114	0.117

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	No Fixed Effects				Country Fixed Effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$	$\ln(\frac{GDP}{Capita})$
L10.$\ln(\frac{GDP}{Capita})$	0.836***	0.852***	0.845***	0.855***	0.930***	0.913***	0.876***	0.851***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L10.% of Pop under 15	-0.0159***	-0.0168***			-0.0127***	-0.0131***	-0.0152***	
	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	
L10.% of Pop over 65	-0.0118	-0.00922			0.116**	0.124***	0.0638	
	(0.057)	(0.097)			(0.003)	(0.000)	(0.097)	
Deg. over 13C, RCP4.5	-0.0282		-0.0214		0.00539			
	(0.190)		(0.186)		(0.800)			
Deg. over 13C, RCP4.5 × L10.$\ln(\frac{GDP}{Capita})$	0.00224		0.00133		-0.00160			
	(0.402)		(0.479)		(0.542)			
L10.Avg. Years of School	0.0160*	0.0192**	0.0172*	0.0234***	0.0170*	0.0191**	0.0755***	0.0773***
	(0.034)	(0.008)	(0.012)	(0.001)	(0.018)	(0.009)	(0.000)	(0.000)
L10.% of Pop under 15 *or* over 65			-0.0164***	-0.0180***				-0.0191***
			(0.000)	(0.000)				(0.000)
L10.% of Pop over 65 × L10.$\ln(\frac{GDP}{Capita})$					-0.0127***	-0.0128***	-0.00648	
					(0.001)	(0.000)	(0.073)	
L10.(Avg. Years of School)^2							-0.00481***	-0.00434***
							(0.000)	(0.000)
Constant	2.229***	2.018***	2.189***	2.064***	1.219**	1.267***	1.564***	2.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Observations	844	844	844	844	844	844	844	844
RMSE	0.363	0.365	0.363	0.365	0.362	0.363	0.360	0.363
R^2 adjusted	0.917	0.917	0.918	0.916	0.918	0.918	0.919	0.918

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

	Base		With under15pct & over65pct		Over65 * lngdppc interaction		All but temp	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$	$\ln(\frac{\text{GDP}}{\text{Capita}})$
L10.$\ln(\frac{\text{GDP}}{\text{Capita}})$	0.836***	0.852***	0.845***	0.855***	0.930***	0.913***	0.876***	0.851***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L10.% of Pop under 15	-0.0159***	-0.0168***			-0.0127***	-0.0131***	-0.0152***	
	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	
L10.% of Pop over 65	-0.0118	-0.00922			0.116**	0.124***	0.0638	
	(0.057)	(0.097)			(0.003)	(0.000)	(0.097)	
Deg. over 13C, RCP4.5	-0.0282		-0.0214		0.00539			
	(0.190)		(0.186)		(0.800)			
Deg. over 13C, RCP4.5 × L10.$\ln(\frac{\text{GDP}}{\text{Capita}})$	0.00224		0.00133		-0.00160			
	(0.402)		(0.479)		(0.542)			
L10.Avg. Years of School	0.0160*	0.0192**	0.0172*	0.0234***	0.0170*	0.0191**	0.0755***	0.0773***
	(0.034)	(0.008)	(0.012)	(0.001)	(0.018)	(0.009)	(0.000)	(0.000)
L10.% of Pop under 15 *or* over 65			-0.0164***	-0.0180***				-0.0191***
			(0.000)	(0.000)				(0.000)
L10.% of Pop over 65 × L10.$\ln(\frac{\text{GDP}}{\text{Capita}})$					-0.0127***	-0.0128***	-0.00648	
					(0.001)	(0.000)	(0.073)	
L10.(Avg. Years of School)^2							-0.00481***	-0.00434***
							(0.000)	(0.000)
Constant	2.229***	2.018***	2.189***	2.064***	1.219**	1.267***	1.564***	2.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Observations	844	844	844	844	844	844	844	844
RMSE	0.363	0.365	0.363	0.365	0.362	0.363	0.360	0.363
R^2 adjusted	0.917	0.917	0.918	0.916	0.918	0.918	0.919	0.918

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$