Estimating the SDGs' Demand for Innovation

Charles Kenny and Dev Patel

Abstract

How much innovation will be needed to meet the United Nations' Sustainable Development Goals? We model shifts in the cross-country relationship between GDP per capita and achievement in key development indicators as "technological gains" and convergence to the best performers at a given income as "policy gains." Assuming that the United Nations' income growth projections for low- and middle-income countries are met, we estimate the residual demand for technology and policy innovation needed to meet several critical targets of the SDGs. Our results suggest that (i) best performers are considerably outperforming the average performance at a given income level, suggesting considerable progress could be achieved through policy change but that (ii) the targets set in the SDGs are unlikely to be met by 2030 without very rapid, ubiquitous technological progress alongside economic growth.

Keywords: Sustainable Development Goals, Preston curves, innovation, technology

JEL Codes: O11, O15, O33

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1 Introduction

The Sustainable Development Goals (SDGs)—development targets for United Nations member states over the next 15 years—are very ambitious. The world has achieved significant progress towards improving the human condition over the past several decades. More children than ever are being educated. Fewer people are living in extreme poverty than ever before. And across the globe, people are living healthier, more free lives. But the progress demanded by the SDGs is more rapid than this historical precedent.

Almost certainly, achieving the Sustainable Development Goals—including bringing 836 million people out of extreme poverty—will require significant technological advance and policy change. But how much, and in what sectors? Where should research be focused, and what are the biggest obstacles ahead? We offer an empirical estimate of the demand for innovation following in the steps of Samuel Preston's landmark paper (Preston, 1975). Applying Preston's principles from life expectancy to a variety of key indicators, we model the relationship between each development goal and a country's income level. We take the movement along the curve produced by a seven percent rate of GDP growth as given and project shifts in the curve over time to predict outcomes in 2030 and compare with SDG targets. We also look at best performance at given income levels to examine how much progress would be achieved if all countries reached best performance standards for their projected income per capita in 2030, then allow for progress in best performance at a given income based on past improvement in best performance at a given income over time.

We define "technology" and "technology requirement" here both broadly and partially. It is anything that allows an improved outcome at a given level of income across all countries. This might be driven by "traditional" technological invention—a cheap and effective vaccine against malaria, for example. But it might just as well be driven by a widely adopted institutional change that increases the efficiency of spending, a widespread shift in spending priorities or outside support. And for some variables we measure (the number of women in parliament, for example), it is likely that "traditional" technologies play a small (direct) role.

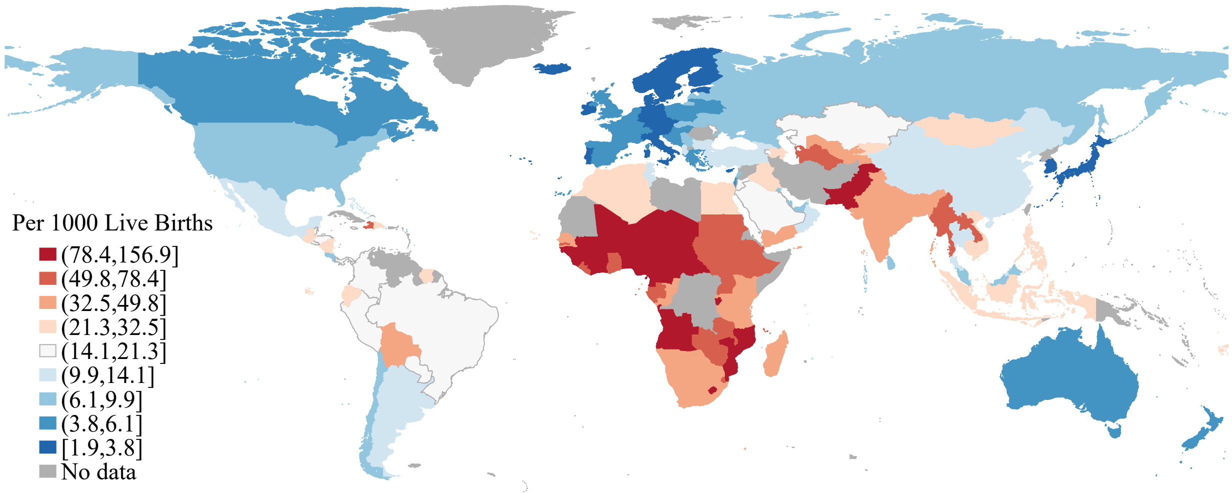
Note also that our definition of "technology" excludes changes that both improve outcomes and income. Take the malaria vaccine again: this may have a dramatic impact on health but through that channel may well increase productivity. Our "technology requirement" measure would only include the impact on health of the malaria vaccine above and beyond the health improvement expected because of income change and the move along a given Preston curve. Similarly we define policy improvement as moving towards best or "frontier" performance –the best outcome achieved by any country at a given income. As measured, this may involve policy choices (potentially those that trade off against delivering other SDGs.) But the performance might also reflect geographic or other factors only somewhat influenced by policy, a technology that is not widely adopted, and/or outlier measurement error.

For many of the 169 SDG targets that were adopted by the UN General Assembly, it is impossible to know definitively whether the target is actually met. We focus on SDGs that meet three criteria. First, the indicators must be quantitatively measurable. Second, the targets must be explicit.[1] Third, there must be a sufficient breadth of available data in terms of the span of years with at least 50 country observations. This reduces the list of targets to those listed below. The resulting set covers 11 targets across 6 of the 17 goals.

- Goal 3: Reduce maternal mortality to under 70 per 100,000 by 2030. Reduce neonatal mortality under 12 per 1,000 by 2030. Reduce under-five mortality to 25 per 1,000 live births.
- Goal 4: Provide primary and secondary education for all by 2030. Achieve gender parity at primary, secondary, and tertiary education levels by 2030.
- Goal 5: Achieve gender parity in the proportion of seats in national parliaments.
- Goal 6: Provide access to clean water and adequate sanitation by 2030.
- Goal 7: Provide universal electricity access by 2030.
- Goal 9: Double industry share of GDP in least developed countries by 2030.

[1] We make two exceptions: we include gender parity among parliamentarians even though the SDGs do not give a date for achieving target 5.5. Additionally, we analyze CO_2 per GDP despite the lack of explicit goal for emissions in the SDGs.

Figure 1: Under-five Mortality Rates Around the World



Note: Figure 1 shows the latest available under 5 mortality rate for each country according to the World Bank's World Development Indicators. Countries in shades of red are above the SDG goal rate of 25, while countries in blues have met the target.

Given the state of some of these indicators around the world today, such as the under-five mortality rate shown in figure 1, achieving the SDGs in the next 13 years is certainly an ambitious task.

Previous analyses of the demands necessary to meet the SDGs have largely focused on financing requirements built up from unit costs of meeting various goals. Such exercises include Stenberg et al. (2016), Hutton and Varughese (2016), Chongcharoentanawat et al. (2016), Greenhill et al. (2015), and United Nations General Assembly (2014). Clemens et al. (2007) criticized a similar literature that set out to cost the achievements of the Millennium Development Goals, noting that progress in meeting MDG targets required more than money.

Previous projection efforts around the SDGs include Karver et al. (2012), Nicolai et al. (2015), Lange and Klasen (2015). These papers have used past rates of individual country progress on individual SDG targets to forecast plausible future progress. Our paper builds on this body of work in several ways. First, we offer a historical analysis at how the relationship between key development outcomes and income has evolved over time from the perspective of technological growth. While previous estimates have focused primarily on health outcomes, we offer comparable estimates for a variety of other key sectors. Second, we study best or "frontier" performance—what is theoretically achievable at a given income as demonstrated by countries providing the best outcomes at or below that given income. Third, we provide empirical estimates of the feasibility of achieving the SDGs. This allows us to quantify the "demand" for technology and/or policy change for each indicator. Given our broad definition of "technology" and "policy", of course, any conclusions will have to be drawn with caution.

This paper proceeds as follows. Section 2 outlines our empirical strategy, and section 3 describes the data used. Section 4 present the results, and section 5 discusses implications for achieving the Sustainable Development Goals. Section 6 concludes.

2 Two Projection Models for Predicting Performance

In order to predict future progress in these key indicators, we adopt two sets of projections: the traditional Preston curve and a "best performer" model that we call the technological frontier. For both models, we use historical performance data from starting year s to ending year e in order to forecast future estimates for each SDG indicator I in country $i \in \mathbb{C}$ and year y. In order to ensure that the relationships are robust, we set a minimum standard for the number of non-missing observations per year. Thus for each indicator I, the period (s, e) is defined as the earliest and latest years for which there is a fixed sample of at least 50 countries in both years with non-missing data.[2] Table 1 lists this period for each indicator. We always assume that GDP growth in the future will meet the SDG target of 7 percent such that for every year after the observed period end e, the GDP is defined as $GDP_{i,e+t} = GDP_{i,e} * 1.07^t$. This provides the key "exogenous" driver of progress in our projections. This growth rate is the explicit goal stated in the SDGs for low- and middle-income countries. We will see that this itself is a hugely ambitious target, and it is unlikely that this will be met consistently for all countries. Thus in some ways, these predictions provide

[2] The exception to this rule is CO_2 KT per GDP PPP Constant 2011. There is sufficient data under these conditions back to 1960. However, given the rapid developments in emissions technology recently, the first year s is set to 2000.

a lower bound on the demand for technology and policy.

2.1 Preston Curves

Our first results will be based on a model that predicts outcomes using the improvement expected from movement along the contemporary Preston curve implied by a seven percent income growth rate to 2030. Then we will model improvement expected from a seven percent annual income growth rate along a Preston curve "shifted" on the basis of past evolution of the cross-country relationship between incomes and outcomes. Equation 1 models the shifting Preston curve. We assume that a shift in the Preston curve signifies technological progress: i.e. that for a given GDP per capita, a better development outcome over time is due solely to technology (broadly defined.) There are several key assumptions inherent in this specification. First, we assume that the functional form of the Preston curve relationship is constant over countries and over time. Second, we follow Pritchett and Viarengo (2010) and assume a double log relationship between income and each SDG goal. In Equation 1, average annual technological growth over the period with starting year s and ending year e is modeled by the parameters $(\hat{\alpha}_{s,e}, \hat{\beta}_{s,e})$. Given the simple Preston curve $ln(I_{i,y}) = \alpha_y + \beta_y * ln\left(\frac{GDP_{i,y}}{Population_{i,y}}\right) + \epsilon_{i,y}$, we calculate $\hat{\alpha}_{s,e}$ according to $\hat{\alpha}_{s,e} = \sum_{y=s+1}^{e} \frac{\alpha_y - \alpha_{y-1}}{e-s} = \frac{\alpha_e - \alpha_s}{e-s}$. The structure is identical for $\hat{\beta}$. Third, we assume that when we estimate the marginal increase in innovation that will be needed in our base specification, the technological progress of the last period will continue during the next period. Formally, we assume $(\hat{\alpha}_{s,e}, \hat{\beta}_{s,e}) = (\hat{\alpha}_{e,e+t}, \hat{\beta}_{e,e+t})\ \forall t$. Figure 2 shows a visualization of these projected shifts. Finally, we assume that no country will become worse off than it is today—that is, we force $I_{i,y}$ to be at least as good as $I_{i,e}$.

$$ln(I_{i,y}) = \alpha_e + \hat{\alpha}_{s,e} * (y-e) + (\beta_e + \hat{\beta}_{s,e} * (y-e)) * ln(\frac{GDP_{i,y}}{Population_{i,y}}) + \epsilon_{i,e_i} \qquad (1)$$

The inclusion of the residual ϵ_{i,e_i} can be interpreted as allowing for a version of country fixed effects. The subscript e_i designates that this residual is taken for the last year for which data for each specific country is available, even if there is data available in more recent years for other countries. This residual is calculated based off a predicted value using all countries with non-missing data for that year (not the fixed sample specification). For countries with no data for a particular indicator, forecast values are on the Preston curve (i.e. the residual is assumed to be zero). The residuals ϵ_{i,e_i} are in themselves interesting, highlighting which countries perform particularly well or particularly poorly given their income. Figure 14 shows that Europe, parts of East Asia, and East Africa perform better than would be expected in terms of under-five mortality given their GDP per capita while the Middle East, Southern and Eastern Africa, and Latin America perform worse. This specification therefore assumes that lead and laggard countries in terms of out- or under-performing on an outcome at a given level of income remain lead or laggard countries to the same extent into the future. Given heteroskedacticity in the Preston curves and higher residuals at low income levels, this likely produces a conservative prediction of outcomes as countries grow over time. We modify the sample of countries used in the base regression to calculate $\left(\hat{\alpha}, \hat{\beta}\right)$ based on a fixed sample of countries—that is, we restrict all regressions to only include those countries for which we have data in year s. Historical data availability is not exogenous (favoring wealthy countries and those that have prioritized data collection). Transitions in Preston curves using all available data in a given year might misattribute a shift to technology when in fact it is non-random changes to the sample. This leaves us with four specifications in a 2×2 matrix: combinations of no shift in the current Preston curve versus assuming technological progress continues at historical rates and including residuals or not.

2.2 Policy Frontier

In a second model, we assume perfect "best policy practice" diffusion by moving to the frontier. That is, we assume that every country i in the set of full countries $\mathbb{C}$ achieves at least as good of a development outcome I as every country that is poorer than i.[3] To take an example, the frontier countries from poorest to richest for under five mortality are the Central African Republic (the poorest country in this dataset), Burundi, Liberia, Malawi, Madagascar, Rwanda, Nepal, Cambodia, Kyrgyzstan, Honduras, Moldova, Jamaica, Armenia, Ukraine, Bosnia and Herzegovina, Montenegro, Belarus, Croatia, Estonia, Cyprus, Slovenia, Finland, Iceland and Luxembourg. Our approach is a simple form of data envelopment analysis. This has the advantage of not assuming a functional form (as opposed to stochastic frontier analysis). It also has the advantage of conceptual concreteness and clarity: countries move to the best outcome that has been achieved in the world today at a given income or below. One drawback of this specification is that outliers may be the result of measurement error rather than genuinely best practice performance. Formally, this frontier is modeled by the indicator function in equation 2 and the maximization function in equation 3. Assume without the loss of generality that a larger I is better. Then under perfect policy diffusion, we assume that each country i with $GDP_i = Y$ shifts to the frontier $F_{I,y}(Y)$ for indicator I in year y. Again, this model is particularly sensitive to countries with large "positive" residuals $I_{i,y}$.[4] This implies that the model is likely to be particularly sensitive to measurement error. Any forecasts of the frontier in 2030 are therefore likely to be over-optimistic. Note also that the "policy frontier" at a particular level of income may be driven by a range of factors apart from the use of the most efficient technologies and may include geographic and demographic factors that improve outcomes at a given level of income (tropical climate of population density, for example), norms, culture and institutional differences that impact the efficiency of spending, spending priorities, and outside assistance, as well as stocks of human and physical capital.

[3]This second model is not applied to the industry size indicator as the target is defined to be country specific.

[4]Positive here is defined as countries with better outcomes than expected for their income, even though depending on the definition of the indicator, this may in fact be below the line of best fit as in Figure 3.

$$\chi(A) = \begin{cases} 1 & GDP_i \in A \\ \\ 0 & GDP_i \notin A \end{cases} \quad (2)$$

$$F_{I,y}(Y) = \max_{\forall i \in \mathbb{C}} I_i * \chi(0, Y) \quad (3)$$

To project future progress, we estimate two distinct scenarios. In the first, the frontier is stable: countries grow at the assumed 7 percent rate and move to the frontier $F(e)$ where e is the most recent year y with available data. In the second, we estimate a shifting frontier assuming continued progress based on the rates for the time period between s and e. (We compute the frontier for s and e, subtract one from the other, divide it by years to get an annual change and then add (2030 - e) times to get a 2030 projection.) This might be taken as a measure of the shifting technological frontier at the level of best policy performance. Unlike in the Preston curve projections, we do not conduct the analyses using fixed samples. We assume that any country with missing data in period s would not be the frontier country for its income. The projected frontier for a given income Y is defined according to equation 4. This specification estimates the change in a given indicator over period (s, e) to future year y assuming that for a given income Y, the historical progress can be linearly projected. Due to country growth, however, for certain segements of the distribution of Y, $F_{I,s} > F_{I,e}$ despite an overall improvement in that indicator. We thus restrict the projected frontier to be at least as good as the frontiers $F_{I,s}$ and $F_{I,e}$ though we do not force this to be true for all years $y \in (s, e)$.

$$F_{I,y}(Y) = \max \left\{ F_{I,s}(Y), F_{I,e}(Y), \frac{(y-e) \times (F_{I,e}(Y) - F_{I,s}(Y))}{e-s} \right\} \quad (4)$$

Figure 2: Shifting Preston Curves (Model 1)

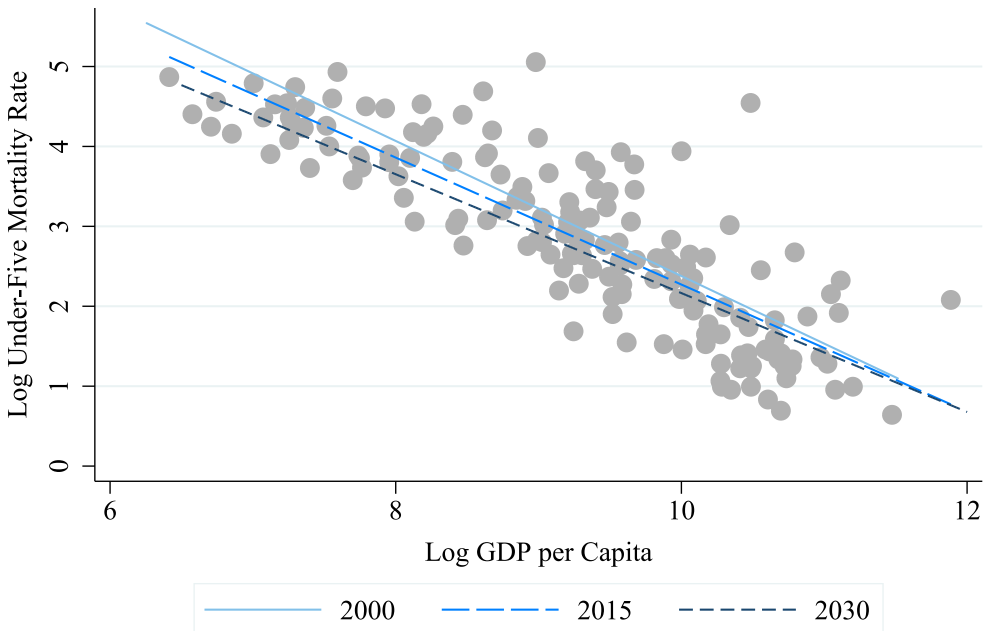
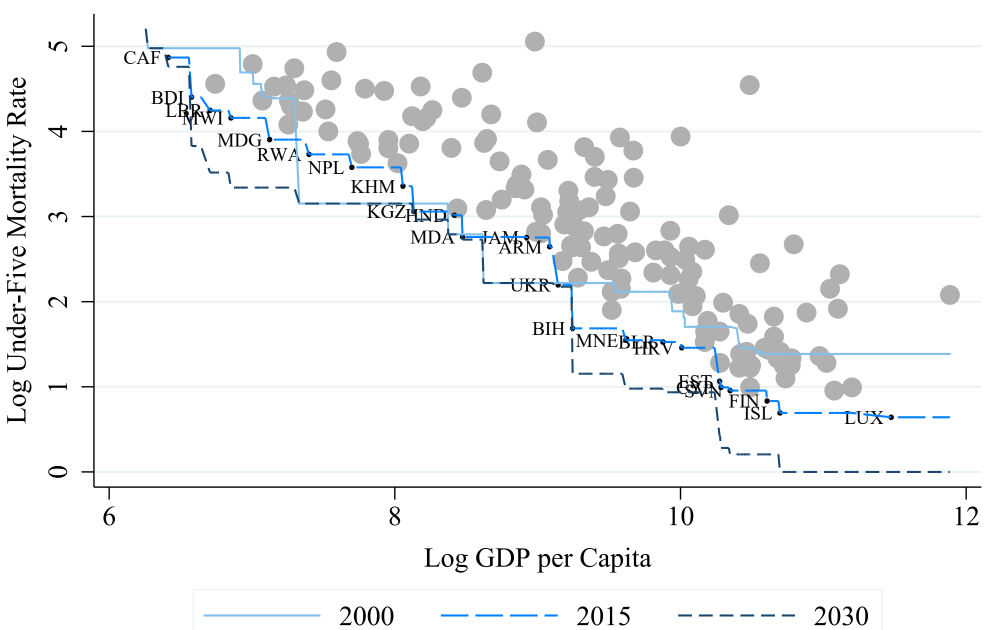


Figure 3: Shifting Technological Frontiers (Model 2)



Note: Figure 2 shows a projected shift in a Preston curve using under-five mortality rate data as modelled in equation 1. Figure 3 shows the evolution of technological frontier for the under-five mortality rate as defined in equations 2 and 3. The solid light blue lines show the Preston curve/frontier in 2000. The long-dashed blue line shows the Preston curve/frontier in 2015. The dashed dark blue line shows the 2030 projection according to equations 1 and 4. Gray dots show countrys in 2015, and black dots show countries that make up the frontier in 2015.

3 Data Sources

All data used in this analysis comes from the World Bank's World Development Indicators, the Penn World Tables version 9, and the United Nations Population Estimates. Table 2 displays summary statistics for each indicator I for the most recent year e available. The GDP projections are calculated assuming a 7 percent annual growth rate from the most recent year of available GDP data. This is the growth rate called for by SDG target 8.1 for the Least Developed Countries. It is an ambitious target: across all countries using all available PWT data, there are only 995 out of 6,719 15-year periods—or 14.8 percent—for which countries achieve a 7 percent annual growth rate. The GDP data used in this analysis comes from the PWT through 2014. To calculate the GDP for each country in 2015, the growth rate of real GDP PPP for each country based on the WDI is applied to the 2014 PWT value. Future GDP per capita is calculated by assuming a 7 percent growth rate and dividing by U.N. population projections.

Table 1: Indicator Basics

Indicator	Goal	First Year	Last Year
CO_2 KT per GDP PPP Constant 2011	N/A	2000	2013
Electricity Access (%)	100	1990	2014
Improved Sanitation Access (%)	100	1990	2015
Improved Water Access (%)	100	1990	2015
Industry Value Added (% of GDP)	Double	1970	2015
Maternal Mortality Rate (per 100,000 live births)	70	1990	2015
Neonatal Mortality Rate (per 1,000 live births)	12	1990	2015
Under-5 Mortality Rate (per 1,000 live births)	25	1960	2015
Net Primary Enrollment Rate	100	1999	2014
Net Secondary Enrollment Rate	100	2000	2014
Primary Enrollment Gender Parity Index	1	1971	2014
Secondary Enrollment Gender Parity Index	1	1971	2014
Tertiary Enrollment Gender Parity Index	1	1971	2014
% Female Parliamentarians	50	1990	2015

Note: Table 1 shows the goal and period (s, e) for each indicator. For industry value added as a share of GDP, the goal is defined as double for all countries whose GDP ppp per capita is below 4,036 dollars for the most recent year available (low and lower-middle income countries.)

Table 2: Summary Statistics

	Mean	SD	N
CO_2 KT per GDP PPP Constant 2011	0.25	0.17	170
Electricity Access (%)	82.11	28.69	170
Improved Sanitation Access (%)	73.77	28.97	153
Improved Water Access (%)	89.93	13.21	155
Industry Value Added (% of GDP)	27.50	10.35	145
Maternal Mortality Rate (per 100,000 live births)	161.56	229.61	158
Neonatal Mortality Rate (per 1,000 live births)	13.24	11.26	162
Under-5 Mortality Rate (per 1,000 live births)	31.10	32.56	162
Net Primary Enrollment Rate	90.52	10.30	110
Net Secondary Enrollment Rate	75.46	22.05	88
Primary Enrollment Gender Parity Index	0.98	0.04	128
Secondary Enrollment Gender Parity Index	0.99	0.11	108
Tertiary Enrollment Gender Parity Index	1.26	0.63	103
% Female Parliamentarians	21.52	11.75	158

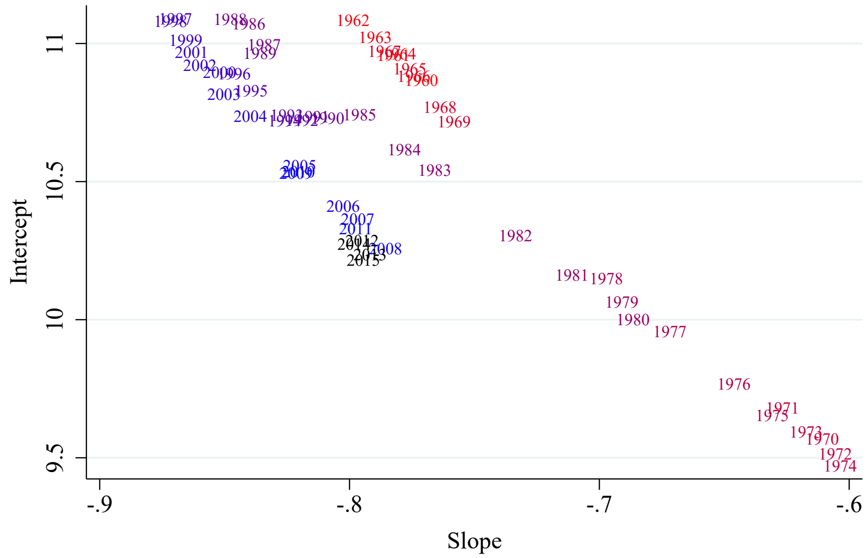
Note: Table 2 shows the mean, standard deviation, and number of countries for each indicator in the end year of the shift period.

4 Projection Estimates

We begin by documenting the historical evolution of the relationship between GDP per capita and these key development indicators. Figure 4 shows how the intercept α and coefficient β have evolved over time for under-five mortality. There seem to be two major changes in the rate of change in Preston curve shifts: first between the 1960s and 1970s, and second at the turn the millennium. In particular, the intercept has began falling while the slope is increasingly less negative for the past two decades or so. Figure 5 shows the Preston curves for the relevant domains and ranges for under-five mortality in five-year increments since 1960.

Figure 6 shows the comparable figure for CO_2 KT per GDP PPP in constant 2011 dollars, documenting a distinct flattening of the Preston curve for carbon efficiency over time. This evolution blends two important trends: first, technological gains in the production process have shifted the energy mix, reducing the CO_2 emitted per kWh of electricity. Second, as poor countries get richer, their energy demand grows faster than their income—to a point.

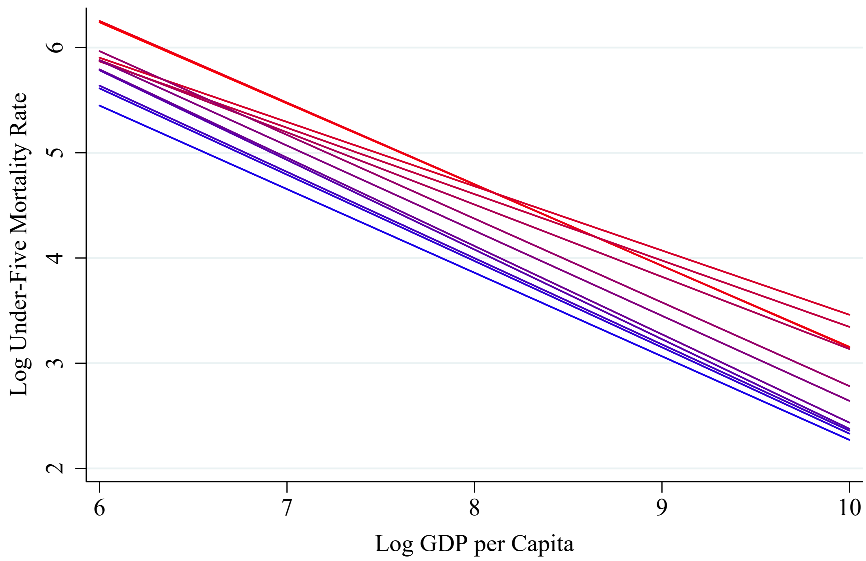
Figure 4: Preston Curve of Under-five Mortality: Change



Note: Figure 4 shows how the intercept α and coefficient β have evolved over time. Brighter red denotes older years, and brighter blue shows more recent years. Data is based off of a fixed sample of countries and a double log Preston model.

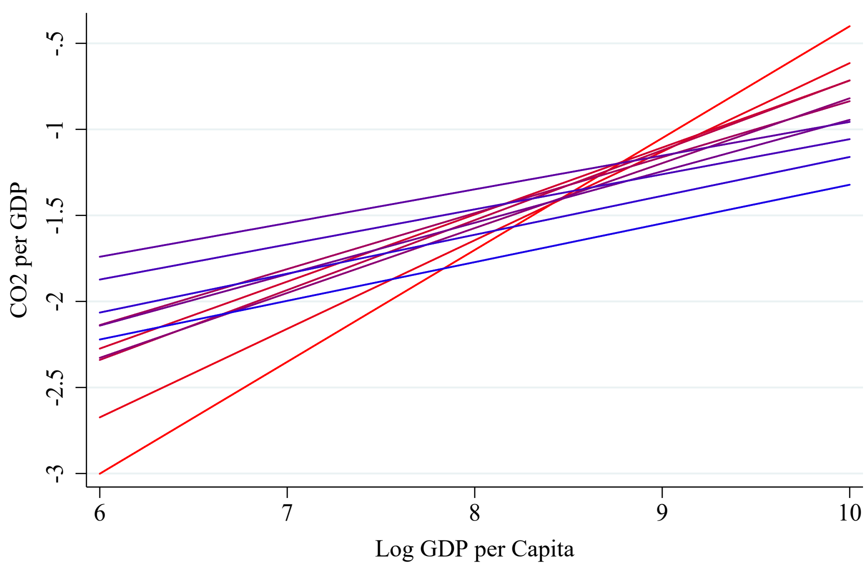
Figures 7 and 8 show under-five mortality projections for select countries according to each Preston and frontier specification. Figure 7 projects outcomes under the scenario of seven percent growth and no shift in the Preston curve, as well as seven percent growth with a shft in the Preston curve. In both cases, results are presented with and without country residual values from 2015. Figure 8 uses the seven percent growth and frontier specification with and without a frontier shift. Figures 15 and 16 showcase select countries and the evolution of their under-five mortality rates under each specification. There are several important trends to note. First, as countries get richer, the estimates converge closer together, reflecting that the shifts are smaller for higher GDPs and that there is substantial heteroskedasticity in the raw Preston curves leading to smaller residuals for richer countries. Second, including the residuals matters much more than adopting a shifting model. To the extent that these residuals capture "country fixed effects," these results highlight the need for policymakers to focus on country-specific actions in order to achieve the SDGs. Third, perhaps obviously, the technological frontier projections are significantly more positive than

Figure 5: Preston Curves of Under-five Mortality Since 1960



Note: Figure 5 shows how the the Preston Curve for under-five mortality has developed in five year increments since 1960. Brighter red denotes older years, and brighter blue shows more recent years. Data is based off of a fixed sample of countries and a double log Preston model.

Figure 6: Preston Curves of CO_2 KT per Constant GDP PPP Since 1960



Note: Figure 6 shows how the the Preston Curve for CO_2 KT per GDP PPP in Constant 2011 dollars has developed in five year increments since 1960. Brighter red denotes older years, and brighter blue shows more recent years. Data is based off of a fixed sample of countries and a double log Preston model.

the Preston curve projections. In fact, every country would easily reach the under-five mortality target by 2030 if it moved to the frontier and the frontier continued to shift as it has been.

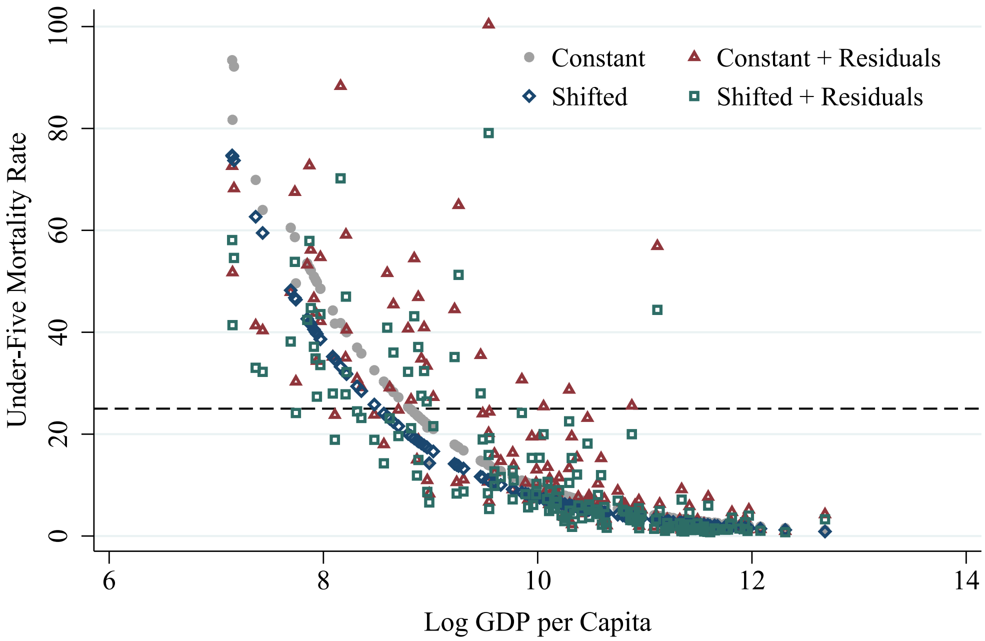
Tables 3 and 4 present the main results. Table 3 presents the mean value for all countries for each indicator across each of the five specifications in 2030 and 2100. In turn, table 4 documents the technological demand needed to meet each of these targets and the number of countries that fail to meet the SDG goal.

Table 3: SDG Indicator Projections in 2030

	Cons. Front. Mean	Cons. Preston Mean	Cons. Preston (Resid.) Mean	Shifted Front. Mean	Shifted Preston Mean	Shifted Preston (Resid.) Mean
CO_2 per GDP	0.02	0.19	0.25	0.02	0.13	0.16
Electricity	97.68	87.78	86.69	99.40	88.27	87.28
Sanitation	95.99	83.53	83.34	98.69	81.34	82.01
Water	98.80	94.43	92.70	100.00	94.76	93.07
Industry	60.96	32.40	30.52	71.89	29.74	27.61
MMR	32.47	62.17	71.65	9.63	64.18	75.31
NMR	4.33	7.02	7.82	1.01	5.86	6.32
U5M	8.65	15.32	17.39	3.68	12.38	13.75
Net Prim. Enroll.	98.94	95.11	94.03	100.00	96.00	94.57
Net Sec. Enroll.	91.97	83.77	83.69	96.04	85.20	84.26
Prim. Gender	1.11	1.00	0.99	1.14	1.02	1.01
Sec. Gender	1.35	1.04	1.01	1.43	1.04	1.03
Tert. Gender	2.35	1.50	1.48	2.70	1.88	1.94
% Female Parl.	63.21	24.94	22.54	99.16	32.44	35.90

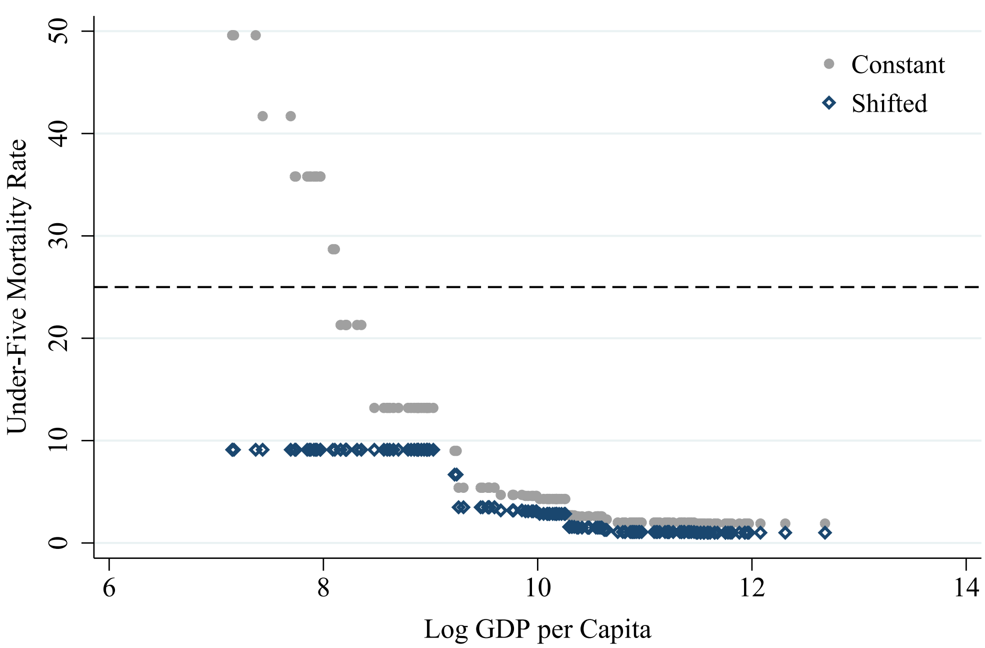
Note: Table 3 shows the estimated country average for each SDG goal under each projection specification in 2030.

Figure 7: Preston Curve Projections of Under-five Mortality in 2030



Note: Figure 7 shows the projected scatter plots of under-five mortality rates and log GDP per capita in 2030 under the four different Preston projection specifications.

Figure 8: Technological Frontier of Under-five Mortality: 2030 Projection



Note: Figure 8 shows the projected scatter plots of under-five mortality rates and log GDP per capita in 2030 under the two different technological frontier specifications.

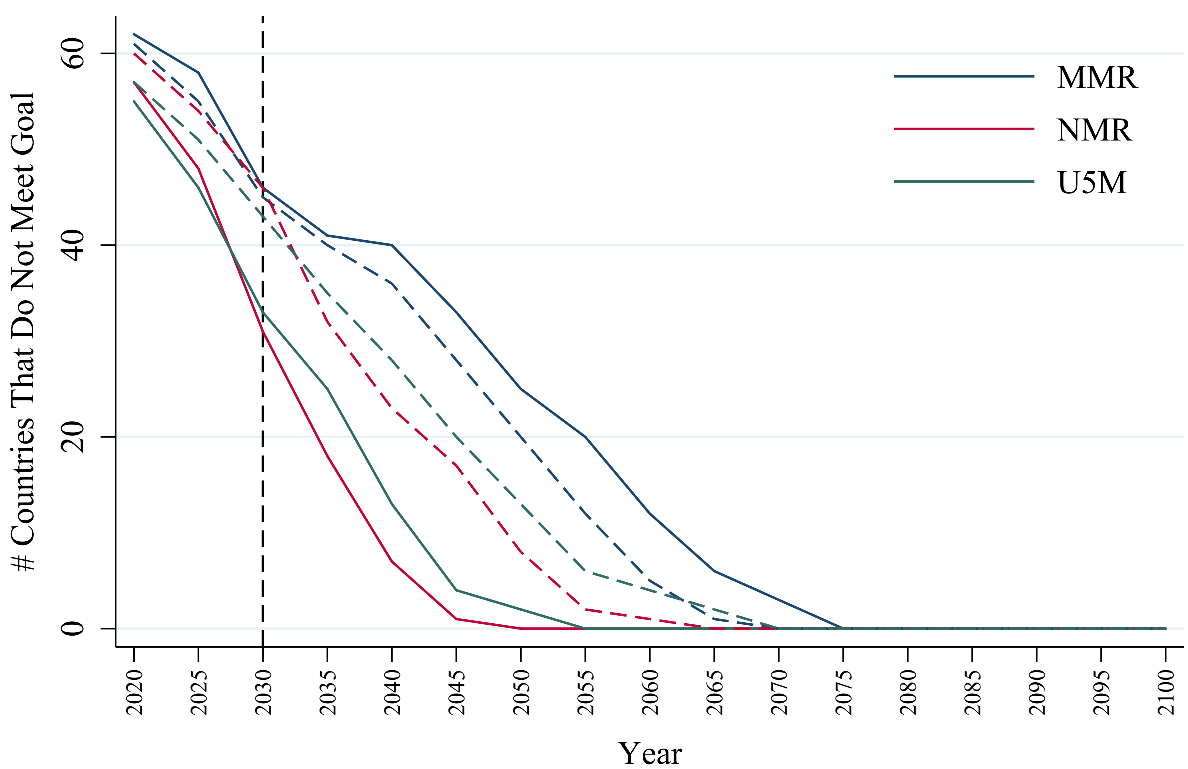
Table 4: Technology Demand Statistics in 2030

	Constant Frontier		Constant Preston		Constant Preston (Residuals)		Shifted Frontier		Shifted Preston		Shifted Preston (Residuals)	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
Electricity Access (%)	15.79	25	31.48	66	51.43	44	8.53	12	24.03	83	48.04	45
Improved Sanitation Access (%)	15.85	42	31.42	87	49.40	56	15.50	14	25.60	121	30.79	97
Improved Water Access (%)	5.71	35	10.00	93	17.66	69	.	0	6.53	134	9.56	121
Industry Value Added (% of GDP)	11.34	28	24.14	64	23.28	66	14.03	12	24.81	64	25.44	66
Maternal Mortality Rate (per 100,000 live births)	216.36	14	143.52	39	147.45	45	8.05	3	142.92	40	151.82	46
Neonatal Mortality Rate (per 1,000 live births)	6.49	18	8.23	30	5.86	46	.	0	7.25	25	4.87	31
Under-5 Mortality Rate (per 1,000 live births)	13.73	18	23.38	31	21.19	43	.	0	18.70	25	15.96	33
Net Primary Enrollment Rate	1.06	164	6.91	116	12.39	79	.	0	4.44	148	7.07	126
Net Secondary Enrollment Rate	8.03	150	27.36	89	37.08	66	13.50	44	23.13	96	28.11	84
Primary Enrollment Gender Parity Index	.	0	0.01	75	0.05	81	.	0	0.01	69	0.03	86
Secondary Enrollment Gender Parity Index	0.02	3	0.05	40	0.13	53	.	0	0.03	42	0.08	60
Tertiary Enrollment Gender Parity Index	0.08	8	0.17	31	0.28	43	.	0	0.05	5	0.32	18
% Female Parliamentarians	10.40	4	25.47	162	27.94	162	.	0	17.88	162	23.19	123

Note: Table 4 shows the mean gap from the SDG goal and the number of countries for all nations that do not reach the goal by 2030. Industry value added estimates only include low and lower-middle income countries as defined by the World Bank's March 2017 classification.

Figure 13 graphically displays this demand for two of the Preston curve specifications: constant and shifting Preston curves, both of which include residuals. A striking takeaway from these figures is that incorporating the "technological" shifts in the Preston curve does not necessarily lead to more progressive results in the case of maternal mortality, depending on a country's place along the income distribution. Figure 17 shows the maternal mortality Preston curves for 1990 and 2015 and highlights this danger of considering estimates from a shifting Preston curve model. Depending on the relative rate of improvement between poor countries and rich countries, the Preston curve at higher incomes can in fact "fall" over time due simply to the rapid progress made in the developing world.

Figure 13: Projected Number of Countries Failing to Meet Health Goals



Note: Figure 13 presents the number of countries that do not meet full access for the maternal mortality rate, neonatal mortality rate, and under-five mortality rate. Dashed lines show constant Preston curve assumptions, while solid lines show shifting Preston curves (both with residuals.)

Breadth of Technology Demand

Figure 9: Preston Projections

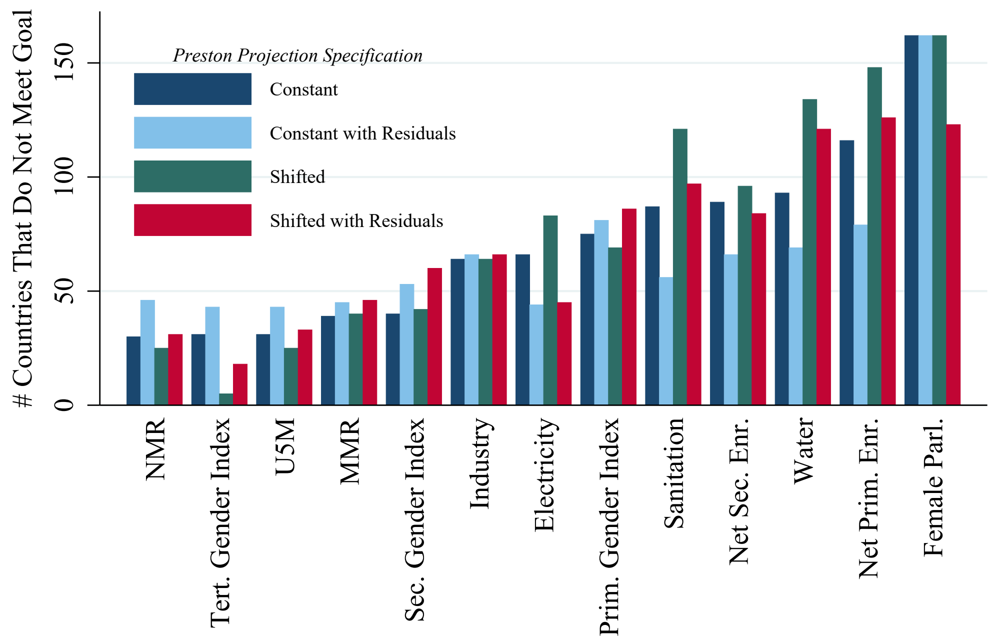
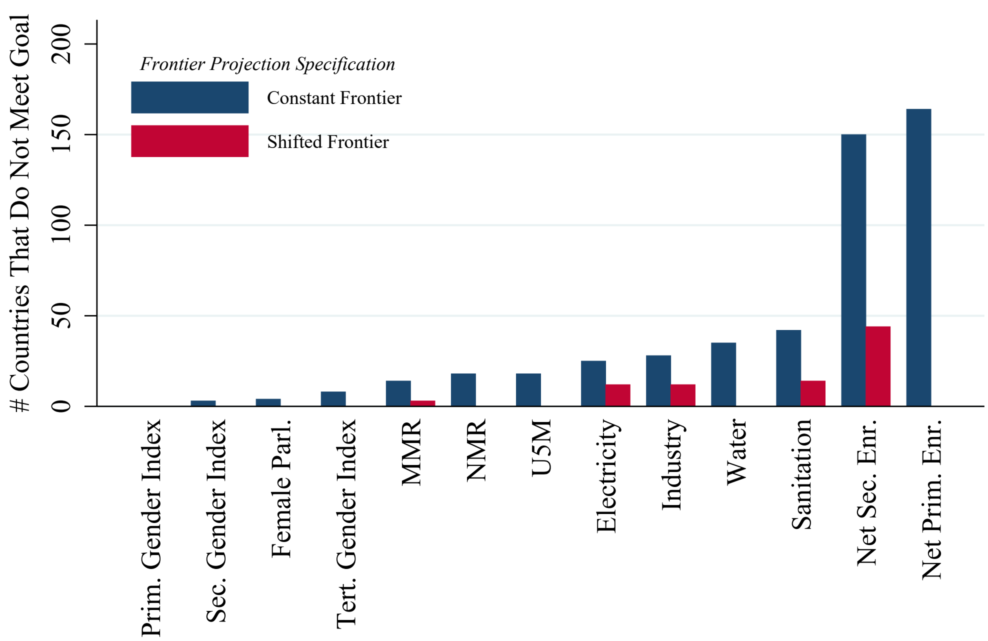


Figure 10: Frontier Projections



Note: Figures 9 and 10 show the number of countries that fail to meet each goal in the year 2030 across indicators for both sets of projection specifications.

Depth of Technology Demand

Figure 11: Preston Projections

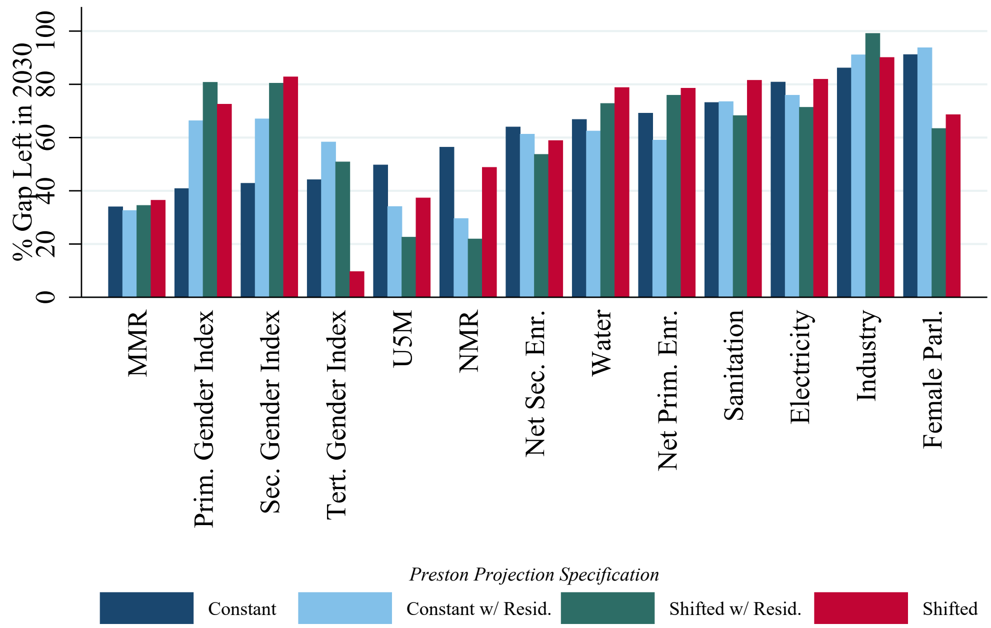
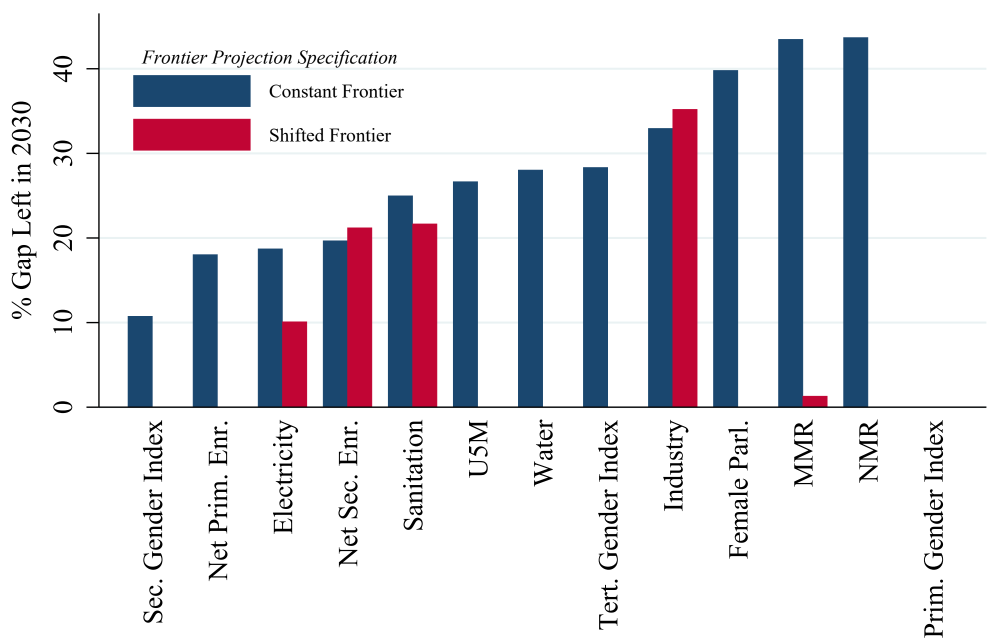


Figure 12: Frontier Projections



Note: Figures 11 and 12 show the average remaining gap for each indicator given as the ratio of the projected gap in 2030 to the gap in the latest year for all countries with positive gaps in both time periods.

5 Implications for Technology and Policy Demand

The model specification has a significant impact on estimating the feasibility of reaching the SDG targets. Almost by construction, the shifted policy frontier projection provides the most optimistic predictions, forecasting that 8 of the 13 indicators in this analysis will be met by every country on time. It is worth reiterating what the shifted frontier demands: first, every country is assumed to grow at seven percent a year to 2030. Then, at their 2030 income, they move to the level of the indicator that is predicted to be achieved by the country with the most positive outcome at or below that income level based on a forecast that best performance improves as rapidly as it has in the recent past. This approach also sweeps aside issues of measurement error likely to be particularly significant with outliers, non-policy factors and tradeoffs across policy choices that may drive outcomes in policy frontier countries. Potentially more realistic forecasts of the frontier using stochastic analysis would be more pessimistic.

But even the constant policy frontier (which does not shift to better outcomes for a given income in 2030) performs largely better than the Preston curve estimates, highlighting that along most of the income distribution, there are countries succeeding *already* in meeting the SDGs. And Table 4 demonstrates that the inclusion of the latest country residuals impact the model much more than whether or not the historical shifts of the Preston curve are continued. The data suggests it may be possible with the body of knowledge that currently exists to bring the maternal mortality ratio of a country with a GDP PPP per capita of $2,848.43 to under 70, for example. In a period as short as 15 years, national policy change may dominate global technology change as the most powerful tool for increasing progress.

At the same time, policymakers have to use the tool, reform is often glacial, and frequently policies get worse rather than better. There is little reason to think enormous policy and institutional improvement is likely within fifteen years. The Preston curve projections retaining residuals likely provide a more reasonable forecast of the world in 2030—although note that the assumption of seven percent growth and continuing rates of technological change still imply they are optimistic. Regardless of the projection model, however, the Preston curve estimates suggest that the targets set for the SDGs are not feasible by 2030 without dramatic technology change more narrowly defined. For most indicators, there are more than 40 countries that will not have met the goals under any of the specifications. This “breadth” challenge is coupled with a “depth” problem: the countries that are expected to not meet the SDGs are not particularly close. The average maternal mortality gap for this set of countries is about 140 per 100,000 live births—a daunting obstacle to overcome. Nevertheless, some targets of the SDGs provide reason to be optimistic. In particular, achieving gender parity in tertiary enrollment rates seems feasible by 2030 without necessarily substantial “technological” improvements.

6 Conclusion

While our results are simply modeling exercises without a true counterfactual, the estimates do give a sense of the feasibility of these targets. These targets are unlikely to be met without significant and unprecedentedly ubiquitous technology and policy change alongside very rapid economic growth. That said, considerable progress is possible both by driving technological change that reduces the financial and institutional burden of achieving development outcomes as well as by moving towards “best practice” in terms of outcomes achieved at a given level of income and global technology availability. If the SDG process encourages that progress, it will have been a success even If specific targets are missed.

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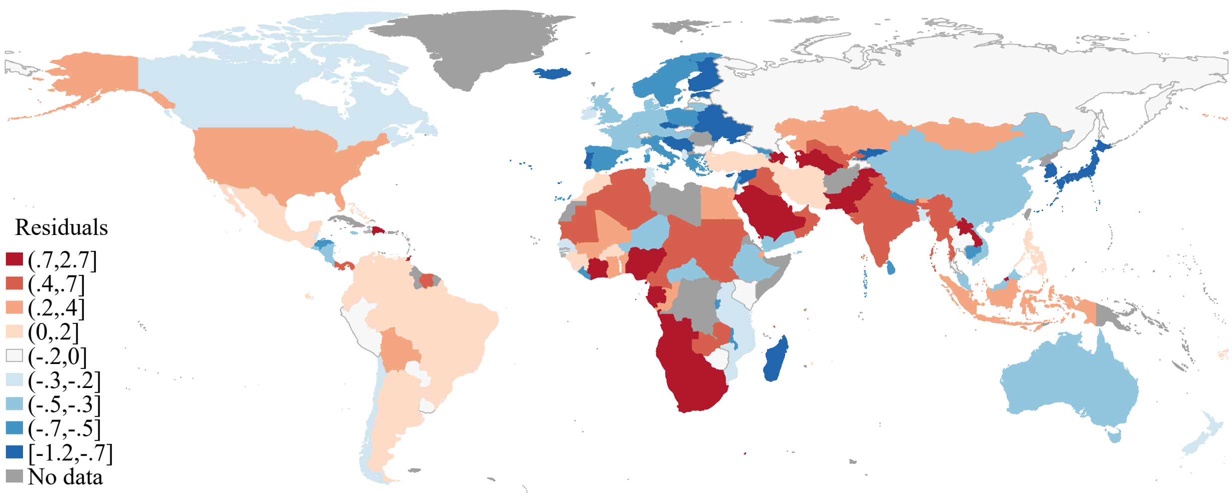
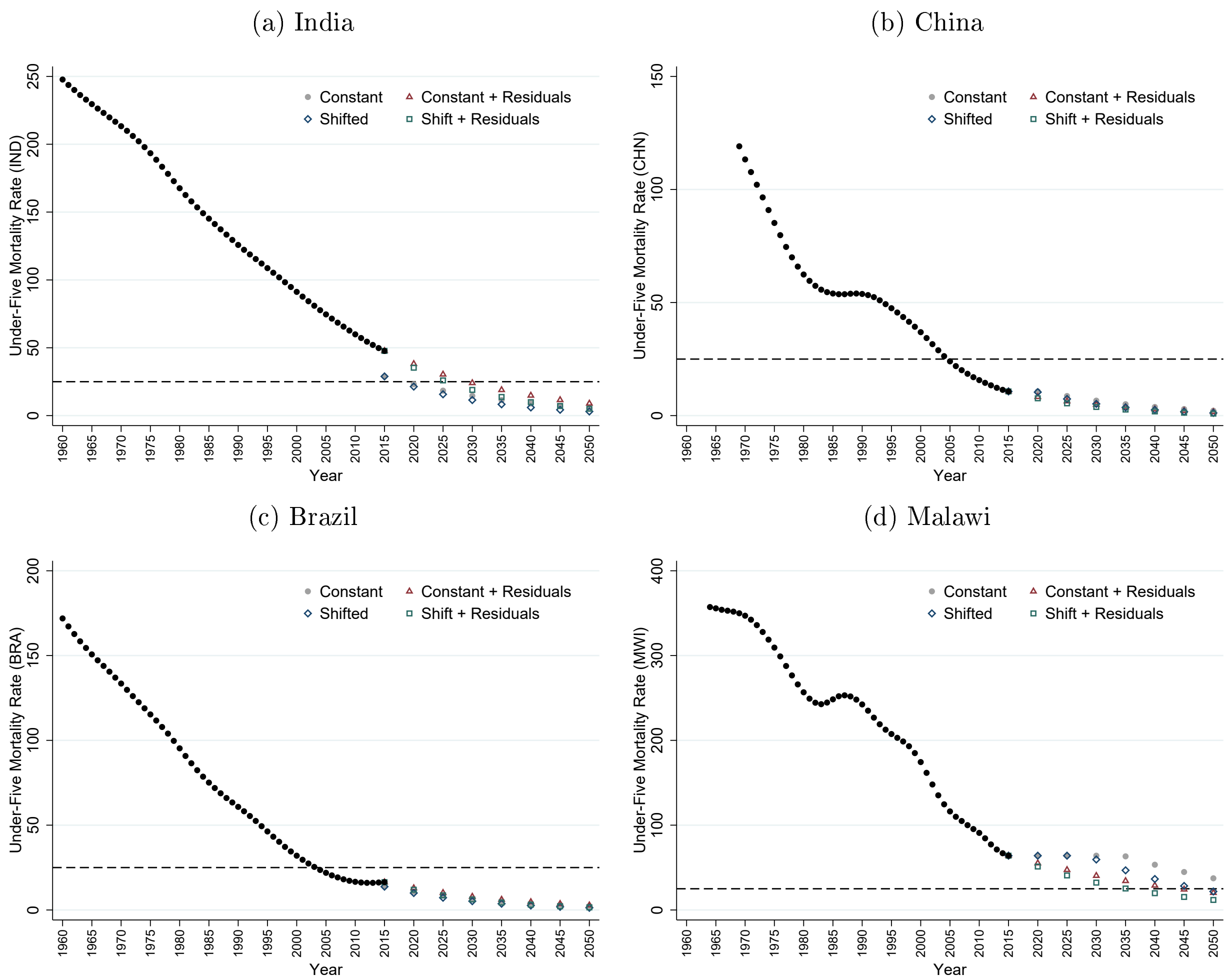
7 Appendix

Figure 14: Under 5 Mortality Rate Residuals



Note: Figure 14 maps the residual value (in log terms) for the under-five mortality rate given a log-log linear relationship with GDP per capita, estimated in the most recent year that each country has available data.

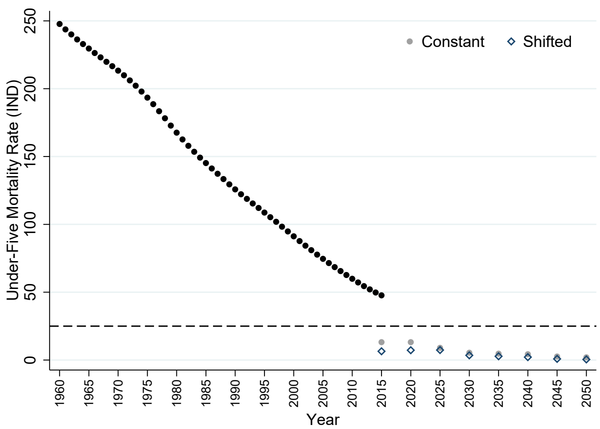
Figure 15: Under 5 Mortality Rate Preston Projections



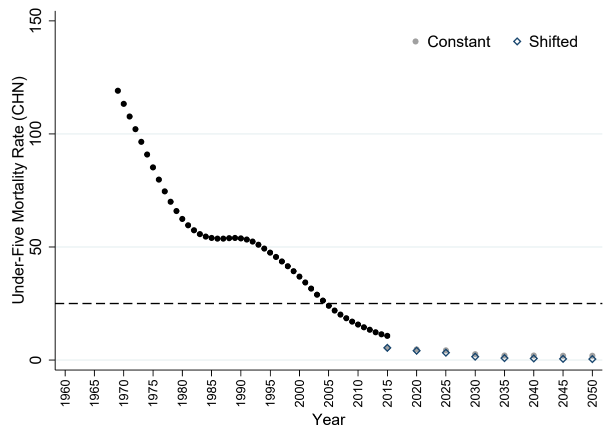
Note: Figure 15 shows the projected under 5 mortality rates for several important countries using the various Preston projection specifications. Observed values show the data available from the World Development Indicators. "Constant" refers to projecting countries by simply moving them along the most recent Preston curve. "Shifted" denotes also shifting this Preston curve using the average annual shift as described in equation 1. "With Residuals" also adds in the residuals for each country's most recent Preston curve to the projection.

Figure 16: Under 5 Mortality Rate Preston Projections

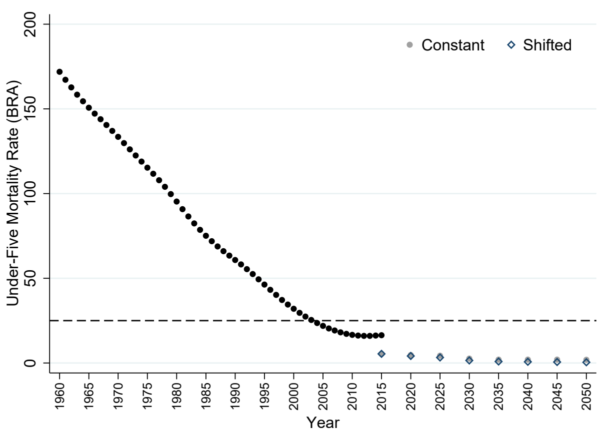
(a) India



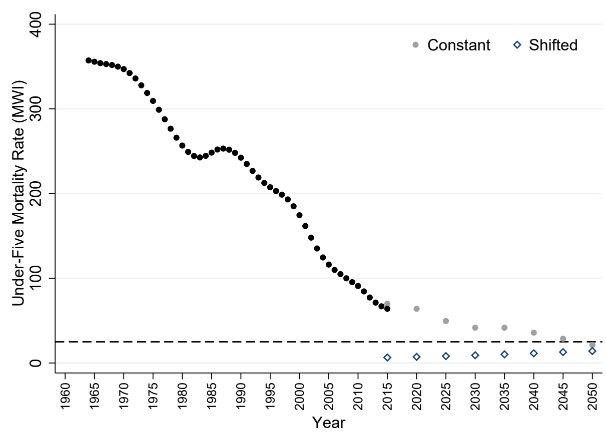
(b) China



(c) Brazil

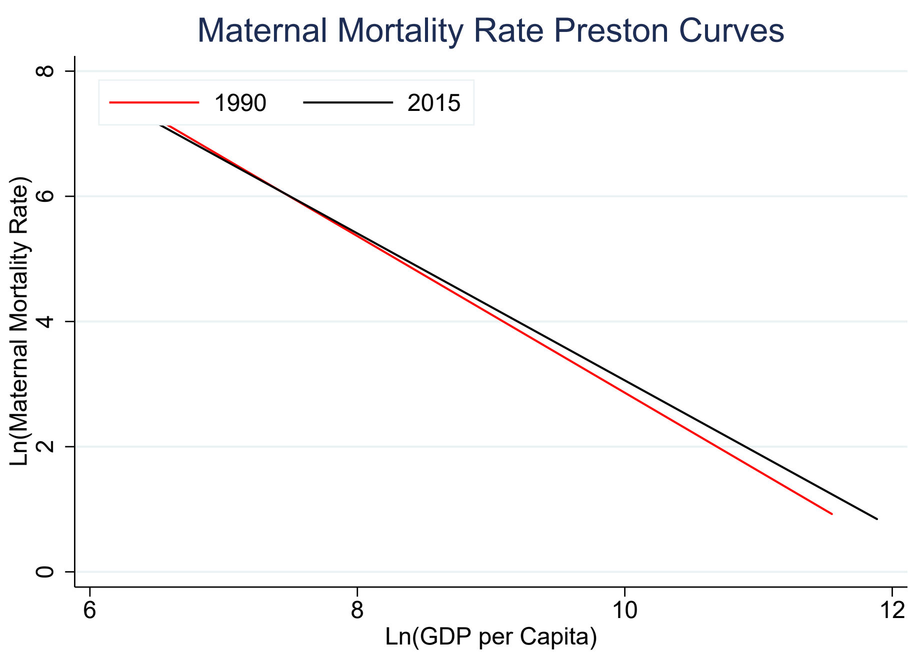


(d) Malawi



Note: Figure 16 shows the projected under 5 mortality rates for several important countries using the various technological frontier projection specifications. Observed values show the data available from the World Development Indicators. "Constant" refers to projecting countries by simply moving them to the current frontier after projecting future growth, while "Shifted" denotes also shifting the Frontier according to equation 4.

Figure 17: Sample Preston Curves for Maternal Mortality Rate



Note: Figure 17 highlights the Preston curves between 1990 and 2015 of the maternal mortality rate.