



International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236-807-536
Fax: +43 2236-807-503
E-mail: riley@iiasa.ac.at
Web: www.iiasa.ac.at

Finance and Sponsored Research

Projections of Educational Attainment and Its Development Impacts for Scenarios of Full and Partial Progress Towards Universal Upper Secondary Schooling

Final Report

Submitted to
The International Commission on Financing Global Education Opportunity

IIASA Contract No. 16-105

May 2016

This paper reports on work of the International Institute for Applied Systems Analysis and has received only limited review. Views or opinions expressed in this report do not necessarily represent those of the Institute its National Member Organizations or other organizations sponsoring the work.

Projections of Educational Attainment
And Its Development Impacts
For Scenarios Of Full and Partial Progress
Towards Universal Upper Secondary Schooling

Bilal Barakat
Wittgenstein Centre for Demography and Global Human Capital /
International Institute for Applied Systems Analysis (IIASA)

May 2016



A Report for
The International Commission on
Financing Global Education Opportunity

Contents

1	Executive Summary	3
2	Scenario definitions	5
2.1	Education Commission scenarios	5
2.2	Wittgenstein Centre attainment-based scenarios	8
3	Projections of development impacts	17
3.1	Health	18
3.2	Economic growth and poverty reduction	21
3.3	Disaster deaths	24
	References	28

1 Executive Summary

Background

It is known that education has strong linkages with virtually all other dimensions of sustainable development, both direct and indirect. Accordingly, trajectories of educational progress towards the Sustainable Development Goals (SDG) education targets are not only of interest on their own terms, but also in terms of their implications for other development outcomes. At the same time, it is clear that for most current low-income countries, meeting the target of universal upper secondary schooling by 2030 outright would require entirely unprecedented rates of expansion that would be extremely challenging to achieve at best. It is highly relevant, therefore, to compare the potential consequences of different scenarios of educational expansion for other development outcomes. Such educational trajectories themselves, like the target, are specified in terms of the participation of school-age children. Many, if not most, of the consequences are determined by the improved education profile of the adult population, however, from whose ranks parents and workers, patients and doctors are drawn. Accordingly, modelling health and economic consequences of educational expansion requires the ability to generate general population projections consistent with given trajectories of educational expansion. The Wittgenstein Centre for Demography and Global Human Capital is a leading centre of expertise in this area and has a proven track record of providing such projections to large-scale international research and policy analysis efforts, including the Intergovernmental Panel on Climate Change (IPCC).

Modelling approach

1. We translate the Commission's two enrolment-based scenarios of educational expansion (baseline trend, accelerated progress at all levels) into scenarios of educational attainment, complemented with additional scenarios derived from attainment directly (baseline trend, universal lower secondary, universal upper secondary).
2. These scenarios feed into a well-established multistate cohort-component human capital projection model, yielding fully disaggregated age-sex-attainment structured population profiles at the country level for most countries of the world up to 2040.
3. Quantitative models for health (under-5 mortality, adult life expectancy), economic outcomes (growth, extreme poverty), and climate change vulnerability (disaster deaths) are applied to the above human capital projections to obtain projections of the potential impact of educational expansion. For the most part, these models allow for differential contributions of each education group in the population, rather than an aggregate education index such as the mean years of schooling. The results bear out the notion that this can have a significant influence on the conclusions.
4. The focus of this particular approach rests on isolating the potential contribution of educational expansion, rather than accounting for feedback or joint dynamics, or producing 'best guess' estimates for other development outcomes on their own terms that would take all relevant factors into account.

Findings and conclusions

1. *Over the medium-term projection horizon that was commissioned*, the contribution to other development goals of additional upper secondary school expansion over and beyond the baseline trend is likely to be relatively modest in general, but meaningfully large for low income countries.

2. Due to the unavoidable inertia intrinsic to population dynamics, many of the development benefits even to rapidly expanding secondary schooling are strongly delayed, but long-lasting. For example, the improved education of 15-year-old girls will only contribute to reduced infant mortality when they eventually enter motherhood (a process that is itself delayed as a result of increased education), but will continue to contribute to a higher income as long as she is of working age. As a result, a time horizon up to 2030, greatly underestimates the longer-term consequences.
3. With respect to health, progress towards eliminating low levels of schooling could make a significant contribution to reducing child mortality, especially in absolute terms. The potential contribution of accelerated progress spread across all levels is rather lower.
4. With respect to economic development, growth in low income countries would benefit in a meaningful way from even partial progress towards universal secondary schooling. While such accelerated progress will remain insufficient to eliminate extreme poverty through its contribution to growth, it could reduce its remaining prevalence by 2040 by a third or even half.
5. With respect to reducing vulnerability to climate events, progress towards universal secondary education could make a significant contribution both in terms of stabilising the pessimistic estimates at current levels and reducing the mean estimates to the tune of tens of thousands of disaster deaths avoided over the coming two decades.
6. The results show that it matters whether increasing *average* education is gained primarily at the bottom or top end of the attainment ladder. Similarly, estimated impacts differ significantly for the two scenarios of partial progress towards the SDG target of universal upper secondary education, depending on whether this takes the form of accelerated expansion across all levels, but without reaching universal participation at any, or the form of universal secondary schooling, albeit universal *lower* secondary schooling. Neither can be expected to lead to uniformly superior development outcomes, instead the relative advantage depends on the outcome of interest.

2 Scenario definitions

As outlined in the summary above, the projections of the potential development impacts of educational expansion towards the SDG targets presented in Part 4 of this report are based on projections of population attainment that are in turn based on various scenarios for educational flows for given reference age groups. Their relationship is best understood in matrix format, with the underlying model on one axis, and the ‘narrative’ on the other.

Table 1: The scenarios examined, by underlying model and level of progress. Labels correspond to sections below.

narrative	enrolment-based (Commission)	attainment-based (WIC)
meeting SDG 4	-	WIC-SDG
ambitious feasible progress	COM-BMK	WIC-ULS
business as usual	COM-TRD	WIC-GET

The difference between the rows is largely self-explanatory. As discussed further below in the context of defining the WIC-ULS scenario, the two feasible progress scenarios differ not only in the underlying data basis, but also in how expansion at different education levels is balanced. This is deliberate in order to provide a range of specifications, rather than merely attempting parallel implementations of equivalent scenarios.

As mentioned previously, the main difference between the two columns, i.e., between the models of educational expansion underlying the Commission’s study of educational financing and the Wittgenstein Centre’s human capital projections is that the former are derived from school-based measures of participation in the form of enrolment, while the latter are derived from population-based measures of educational attainment. While these inputs are highly correlated, each has its own strengths and weaknesses. Gross enrolment figures may contain substantial reporting bias, and are distorted in the presence of overage enrolments. At the same time, they are often more current and available on an annual basis. Attainment data is usually collected from in surveys from the individuals concerned (or a household proxy respondent), who face less incentive for misreporting than administrative informants. However, such data rely on large-scale surveys or censuses that are often many years apart, and moreover completed individual attainment is only observed retrospectively, several years after those concerned have already left school.

Accordingly, it is useful to compare the results from both approaches. However, *both* enrolment-derived and attainment-derived education scenarios are ultimately translated into population *attainment* projections. The reason is that the subsequent projections of the potential impacts of educational expansion necessarily rely on such inputs, simply because that is the form the evidence-base takes. To the extent that empirical data on educational differentials in the adult population with respect to health, for example, are available at all, they are invariably specified with respect to some measure of attainment at the time of survey, not enrolment status in childhood.

Further detail on the rationale and assumptions underlying each of these scenarios are presented in the following.

2.1 Education Commission scenarios

Two scenarios were provided by the Commission for use as input into the Wittgenstein Centre human capital projection model. Both are estimated on recent enrolment data. Their assumptions

are outlined on their own terms in the following, before discussing the steps that are necessary to transform them into input scenarios that can be used in a model of population attainment.

2.1.1 Commission Baseline Trend (COM-TRD) scenario

This scenario is estimated on Gross Intake Rates (GIR) into the last grade of primary and secondary school, and Gross Enrolment Ratios (GER) for tertiary education. In each case, the average growth rate (at the original indicator scale) over the period 2010–2014 is calculated. For the projection, it is assumed that the growth rate at a given value of the indicator is a linear function declining to zero at 100 percent participation. Mathematically, this is equivalent to assuming logistic growth with a constant trend at the logit scale. Gross rates can exceed 100 percent due to overage enrolment, these are capped at 100 percent. The raw scenario is not gender-specific.

2.1.2 Commission Benchmark (COM-BMK) scenario

The COM-BMK scenario is structurally identical to COM-TRD above, but starting in 2015, the global average of the top 25 percent of country-specific growth rates is applied to all countries instead of their individual historic rates. In other words, all countries adopt a single global benchmark rate of expansion.

2.1.3 Linking enrolment-based expansion scenarios with the attainment-based population model

Before the above scenarios can be used in the Wittgenstein Centre population attainment model, several imputations and adjustments are necessary.

1. Enrolment-based indicators in a given year must be matched to attainment of a particular cohort in a particular year.
2. These figures must be disaggregated into female and male attainments.
3. Additional education levels, namely *incomplete* primary and lower secondary must be imputed.
4. The logical constraint must be imposed that (for a given cohort) attainment at higher levels cannot exceed that at lower levels. For example, the share of individuals with at least secondary schooling cannot exceed the share with at least primary schooling.
5. While not a logical necessity, a ceiling for tertiary attainment at 90 percent is imposed for comparability with the existing Wittgenstein Centre scenarios.

Mapping enrolment to attainment

Given sufficiently long time series for both enrolment and attainment indicators for a large number of countries, an attempt could be made to empirically estimate the relationship between enrolment ratios of, say, 18-year-olds in some year and secondary attainment of 33-year-olds fifteen years later. Unfortunately, on currently available data such an exercise would be fraught with difficulties of its own. Absent existing robust estimates of these relationships that could be used 'off the shelf', there is no alternative but to use suitable enrolment-based indicators directly as proxies for attainment. As a matter of fact, this approach is consistent with current practice in international education statistics, were the 'primary completion rate', for instance, is actually operationalised as the GIR into the last grade of primary. This equivalence is expected to be poorest at the tertiary level, where both the age of de facto participants and the length of time they are enrolled varies to a much greater extent than at school.

In effect, this means that the GIR for primary is taken to indicate the primary attainment of the age group 10–14, the GIR for secondary the upper secondary attainment of the age group 15–19, and the tertiary GER the post-secondary and tertiary attainment of the age group 20–24. While the mapping of ages is not exact, some ‘fuzziness’ is unavoidable, since the population projection in any case operates on 5-year age groups in 5-year time steps.

Invariably, a population projection requires a baseline population as a starting point. Attainment-disaggregated population projections require baseline attainment profiles for all age groups. Since even given the above mapping, the enrolment data fails to provide this (deriving the primary attainment of 50-year-olds in 2015 would call for enrolment figures from the mid-1970s, which are in many cases not available). Similarly, for the cohort that is aged 10–14 in 2014, the enrolment figures provide no indication of their ultimate secondary or tertiary attainment. Both kinds of gaps in the attainment profile were imputed with the corresponding figures from the Wittgenstein Centre’s attainment database. Given the lack of exact correspondence between gross enrolments and attainment due to overage enrolment on the one hand and late attainment on the other, this creates some unavoidable discontinuities at the country-level. However, the aggregate results at the level of income groups remain reasonably smooth.

Gender disaggregation

In order to generate female and male series from the trajectory for both sexes combined, we first determine the gender gap (in percentage points) evident in 2010 in the Wittgenstein Centre’s baseline attainment data. This spread is applied to the scenario for its average. Due to time constraints, equal weights are assumed for males and females. In addition, future sex ratios are endogenous, since survival is affected by attainment in our projection. As a result, these future sex ratios are not available a priori, in order to inform the gender disaggregation of the Commission scenarios. The gender gap is linearly reduced to zero by 2040, for both Commission scenarios. Where the total figure approaches 100 percent, the above approach may push the higher-attaining group above this limit. In these cases, their attainment was reduced, with an offsetting increase for the other group in order to maintain the assumed trajectory for the total.

Interpolation of additional education levels

The Commission scenarios are, in the first instance, defined for three education levels: primary, upper secondary, and tertiary. A fourth level, ‘no education’, can be defined implicitly via the residual. In other words, if 90 percent have attained primary education or higher, then 10 percent have not even primary attainment. The Wittgenstein Centre’s population-attainment model uses six levels. To the above four are added incomplete primary and lower secondary. These levels for which no information is contained in the original Commission scenarios are interpolated. Specifically for this purpose, an attainment projection is generated that applies the principles of COM-BMK to the Wittgenstein Centre’s attainment projection, i.e. projecting all countries forward with the average expansion rate of the top 25 percent. From this projection, the interpolation weights for each year are extracted that relate incomplete primary attainment and lower secondary attainment to no education/completed primary and completed primary/upper secondary respectively. These weights are used to interpolate the missing levels in the Commission scenarios.

Rank and ceiling constraints

In the next step, the resulting trajectories are adjusted such that attainment at lower level at least matches that at higher levels. For example, if the above procedure yields a projected share of 70

percent primary attainment (for a given cohort in a given year), but 75 percent lower secondary, primary attainment is likewise increased to 75 percent. Such cases may arise since each level is projected separately to begin with.

Finally, the projected increases in tertiary attainment exceeding the last empirically-observed level are proportionately scaled downwards such that the saturation level of the logistic growth model is at 90 percent.

2.2 Wittgenstein Centre attainment-based scenarios

In addition to the Commission scenarios described above that are derived from recent trends in enrolments, we present for three scenarios specified in terms of ultimate educational attainment directly. This comparison can serve to identify results that may be due to potential inconsistencies associated with integrating the Commission's enrolment-based scenarios with population projections disaggregated by attainment. In addition, this provides an additional scenario against which the 'feasible progress' can be compared, namely one of fully meeting the SDG target. Finally, the attainment-based scenarios have been generated, and their impacts analysed, for a longer projection horizon.

The three attainment-based scenarios are:

1. a baseline trend extrapolation (WIC-GET: Global Education Trend),
2. a 'feasibly progress' scenario defined according to the same underlying benchmarking logic as the Commission's, but within the specification of the Wittgenstein Centre's own attainment projection (WIC-BMK: Benchmark),
3. a scenario of universal upper secondary participation by 2030 (WIC-SDG).

All three are based on the latest iteration of the Wittgenstein Centre's long-term educational attainment projection model. Its key properties are described in the following. The population model that these attainment projections feed into as exogenous input are already fully documented in Lutz et al. (2014).

Summary of the WIC attainment projection model

The scenarios of educational expansion underlying the population projections presented here result from a further refinement of the education model presented in Lutz et al. (2014). In summary, we project the share of the population ever reaching or exceeding a given attainment level. This is done separately by country, and gender, but with 'shrinkage' within a Bayesian framework (with weakly informative priors). The mean expansion trajectories are modelled as random walks with drift (and potential mean reversion) and independent noise at a probit-transformed scale. The trend parameters are estimated based on reconstructed attainment histories, and extrapolated, subject to additional and some exogenously imposed convergence within regions and between females and males. Under the target scenarios, SDG targets are treated as 'future data' (in other words, target trajectories are modeled looking back from 2030 under the assumption that the target will have been met), with a potential trend break in 2015.

Limitations shared with all existing global projections of educational development include the fact that in the absence of a detailed theoretical basis, they are forced to rely heavily on statistical extrapolations. For example, there is little consensus on whether "higher education is the new secondary education" (as claimed by Andreas Schleicher of OECD), or is fundamentally different from lower

levels of schooling (e.g. in terms of institutional framework, its role in the life cycle, economic returns). In addition, global projections can necessarily not account in a satisfactory manner for idiosyncratic policy changes or shocks. In addition, the specific modelling choices outlined above imply a number of trade-offs. Using highest school attainment as the underlying measure solves many problems associated with historic enrolment data by allowing the consistent reconstruction of time series of attainment from relatively recent cross-sectional data, but comes with challenges of its own. While nevertheless preferable overall, the principal disadvantage of attainment measures deserves mention, namely the relatively long time lag with which outcomes can be observed. Late attainment is common in many developing countries, so that attainment cannot safely be assumed to be 'final' until several years above the typical graduation age.

The model operates on 5-year age groups and in 5-year time steps. While the starting (2015) and target (2030) years for the SDGs conveniently line up with this grid, typical durations and graduation ages for different attainment levels unfortunately do not. The target is interpreted such that the cohort aged 15-19 in 2030 will ultimately (not necessarily already at that age, which would be too early for the 15-year-olds with respect to upper secondary) universally attain secondary education. In order to ensure that most late attainment is captured, completed primary attainment is observed at age 15-19, completed lower secondary at age 20-24, and completed upper secondary and post-secondary by 25-29. The latter is likely to underestimate the amount of post-secondary attainment somewhat, but an even higher reference age would come at the cost of an even greater time lag and less current observational data.

The basic model specifies that the inverse probit of the share attaining a given education level or higher among the entire cohort follows a random walk with country-specific drift. In principle, the specification also allows for mean-reversion by partially backtracking an (estimated) proportion of the random shock of the previous period, but in practice no meaningful mean-reversion of this kind was picked up from the data. This is not necessarily surprising, given that mean-reversion on a year-on-year basis will largely be obscured by the 5-yearly data.

Additional complexity is layered over this basic model. Gender convergence is specified such that at each time step, the predicted values for both genders are shifted towards their joint average. An additional level of independent errors of small magnitude that do not persist in the random walk and do not enter the gender convergence is allowed in fitting the observed data, in order to account for exogenous errors at the level of data, rather than in the underlying educational process.

Limitations/Constraints

While the above model in many ways advances the state-of-the-art in long-term education projections, there remain a number of incidental and fundamental limitations.

While most countries of the world are included in the baseline data and the estimation, representing well over 95 percent of the world population, there are some gaps in country coverage. More importantly, these gaps are not random. One category of countries that is difficult to include, but ultimately not consequential in terms of the projections, are small island states. More problematic is the fact that, since the baseline data build on censuses and large-scale surveys, a minimum level of security and state capacity is normally required for countries to be included. Conversely, this means that 'failed states' and countries suffering from violent conflict are underrepresented in the data. Assuming these countries also exhibit below-average rates of educational expansion, this means that overall and regional trends are biased upwards to some extent in their absence. Alternatively, the estimates may be interpreted as being unbiased, but conceptually restricted to representing the range

of ‘non-catastrophic’ scenarios, the same way that even the ‘low’ projections of global population by the UN do not take into account the possibility of catastrophic disease pandemics.

Another data-related constraint has already been discussed, namely the unavoidable time lag associated with completed attainment. In the present context, this limitation is highlighted further because with baseline data from 2000 to 2010, the inability to pick up on the most recent trends in *enrolments* potentially underestimates the contribution of EFA and MDG related educational expansion to long-term trends. However, the verdict is still out to what extent such a contribution actually occurred at all. While there certainly were cases of strong enrolment growth during that period, the present projections show that significant growth was anyhow to be expected. Indeed, at the aggregate level, our results are broadly consistent with existing extrapolations based on enrolment/attendance, suggesting that, in practice, the time lag of attainment is not particularly problematic.

Perhaps the biggest conceptual constraint is that attainment contains no measure of quality. Neither does enrolment or attendance, of course, and measuring quality is generally recognised as one of the single greatest unsolved challenges in international education statistics, matched only, perhaps, by the challenge of measuring equity. To some extent, this is therefore a data problem, that cannot currently be resolved. Existing efforts to derive general quality indices from international assessments are not without problems, and in any case are currently too limited to country coverage to provide a comprehensive solution. More generalisable perhaps, but even further removed from educational conceptions of quality, are efforts to estimate quality by differences in economic returns to nominally equivalent attainment levels that immigrants from different countries command in the US labour market, for instance. In any case, the challenge of modelling and projecting educational quality cannot feasibly be overcome within the scope of the present exercise.

Implementation

Formally, the core model can be cast in a formula as:

$$y_{c,t,g} = \Phi \lambda_{c,t,g} + \epsilon_{c,t,g}$$

$$\lambda_{c,t,g} = \lambda_{c,t-1,g} + \tau_{c,g} + u_{c,t,g} - \theta u_{c,t-1,g},$$

where $y_{c,t,g}$ is the share between zero and one reaching a given attainment level (index omitted) in country c at time t among gender g , $\lambda_{c,t,g}$ is the predictor of y at the transformed scale, the ϵ are the ‘data error’ layer, and the u the random ‘shocks’ to attainment. The λ follow a random walk, starting from the last position at each step, but potentially retracing a share θ of the previous period’s shock. The key parameter of interest for our purposes is τ , capturing the country-specific drift (or ‘trend’).

The above basic model is complicated further by the presence of gender convergence, which is defined through the expression:

$$\lambda'_{c,t,g=i} = \nu_{c,t} \times \lambda'_{c,t,g=i} + (1 - \nu_{c,t}) \times \lambda'_{c,t,g=-i},$$

and replacing λ with λ' in the definition of y .

In target scenarios, $\tau_{c,g}$ is replaced by

$$\tau'_{c,t,g} = \begin{cases} \tau_{c,g}, & \text{if } t \leq t' \\ \tau_{c,g} + \delta_{c,g}, & \text{if } t > t' \end{cases},$$

where t' is the ‘take-off’ time for the target scenario (e.g. 2015 for the SDGs) — suitably shifted to account for the age group actually modeled, as described above — and δ is the unconstrained ‘boost’ required to achieve the target (which is treated as a ‘future observation’).

In terms of prior distributions, vague priors are specified that only incorporate knowledge of the order-of-magnitude of various effects, as well as logical bounds.

The mean-reversion effect θ has a Beta(1.5, 1.5) prior in the interval (0, 1). The empirical gender convergence factor ν is level and country specific, with prior Beta(1, 5), to ensure a value in the interval (0, 1), strongly skewed towards smaller values. True initial levels are given conceptually uninformative ‘flat’ priors, but restricted to the interval (-4, 4) to ensure a proper posterior. The idiosyncratic shocks at the probit scale, i.e. the gender, level, year, and country specific epsilons, are i.i.d. draws from a Gaussian distribution with zero mean and standard error σ_ϵ . The additional errors stem from a Gaussian N(0, 0.05) distribution. The (gender, level, and country specific) drift parameters have Gaussian priors centred on regional means (themselves drawn from a Gaussian N(0, 1) distribution), with standard error σ_{trend} . The hyper-priors on variance parameters σ_ϵ and σ_{trend} are Gaussian with mean zero and variance 0.2.

The model was implemented in the ‘Stan’ software package and posteriors samples generated through MCMC sampling. Chains converge consistently in around 100 iterations, and a total of 500 samples was kept from four chains after discarding burn-in and checking Gelman’s ‘R hat’ split-chain convergence criterion. The number of posterior samples is constrained not only by computation time, but also by the large number of scenario-time-country-level-gender-specific parameters (163 countries, 2 genders, 5 education levels, 2 scenarios, 28 time steps). For each scenario, storage of the results requires more than 5 MB per iteration. However, even 500 samples in fact results in projection quantiles that are sufficiently smooth.

The empirical historic expansion patterns are estimated on a recent set of global reconstructed time series of completed educational attainment (Lutz et al. 2014). These are disaggregated by country, year in the range 1970-2010, gender, 5-year age groups, and six education levels: none, incomplete primary, primary, lower secondary, upper secondary, post-secondary. The latter is an aggregate category that includes, but is explicitly not limited to, tertiary education. These time series were reconstructed from the most recent available large-scale cross-sectional baseline data. In most cases, that means either censuses or standard international household surveys, such as the DHS. The consolidated and harmonised baseline data were backprojected along cohort lines, accounting for educational mortality differentials. As an illustration of the basic principle, and ignoring said mortality selection, the share of 50-year-olds with at least upper secondary education in the year 2000 informs us of the likely share of 40-year-olds in 1990. Where possible, these backprojections were validated against historic data sources.

In the present exercise, 163 countries were included that could be nested within GEMR world regions and World Bank income groups. These cover a vast majority of the global population, and most exclusions are small (island) states.

The key advantage of this dataset is firstly its large coverage, that is not limited to countries with historic time series data, and secondly consistency, since all attainment statuses are determined at the same point in time, thus avoiding as much as possible the problem of changing definitions over time. Differences in definitions between countries are harmonised through the ISCED classification scheme and case-by-case validation.

The main disadvantage of this approach is the relatively large time lag. Firstly, the baseline data itself (with censuses normally only conducted every ten years). Secondly, because formal educational

attainment can only be assumed to be essentially completed at ages adult ages (depending on the specific level), the effect of very recent or ongoing changes in enrolment trends are not reflected.

2.2.1 WIC Global Education Trend (WIC-GET) scenario

Overview

Given the above model, the WIC-GET scenario arises naturally as an extrapolation of the estimated country-gender-level-specific trends into the future. Some additional adjustments are made to the projected trajectories. Country trends (level and gender specific) linearly converge over six time steps to the regional trend. The strength of gender convergence increased in two steps to reach twice the past empirical value. The logical inequality relations between the participation shares (e.g. that the share attaining secondary or higher must be less than the share attaining primary or higher) is enforced by capping participation at the higher attainment at the level of the prerequisite attainment. Projected attainment at the post-secondary level is rescaled to remain below 90 percent, based on substantive reasoning. These adjustments are explained in greater detail in the following.

Details

The first adjustment consists of a small amount of cross-country convergence within world regions is imposed. Specifically, we converge the country-specific drifts simply by reducing the scale parameter that determines their variation around the regional average. In particular, the scale is shrunk to zero linearly over 6 steps (i.e. thirty years). Such a relatively slow convergence avoids abruptly stopping the rapid expansion among the frontrunners. Note that it is the drift parameters that converge, not the attainments as such. This approach implies that convergence is to an *unweighted* regional mean. Whether this is appropriate for regional ‘heavyweights’ such as China and India, but perhaps also Nigeria, for example, is a matter for debate. We have chosen to model education *systems* as the unit of analysis. The regional groupings are derived from the GEMR regions, with Australia and New Zealand combined with North America and Europe for purposes of convergence. In addition to normative expectations regarding educational development and international benchmarking, some degree of cross-country convergence serves to stabilise the projections, because countries with a historically stagnating or even declining trend are not projected to undergo complete educational collapse, but to eventually be ‘pulled up’ onto a more typical positive trajectory.

The second adjustment consists of increasing the amount of gender convergence beyond the empirically estimated amount. One reason for doing so is that the completed attainment data may not fully reflect the most recent developments during the EFA period 2000-2015 and may therefore underestimate the amount of gender-convergence. During the projection period, the parameter capturing the amount of gender convergence (see model description above) is increased proportionately up to twice times its historical value (with multiplication factors increasing linearly over two time steps), capped at 0.5. This increase was calibrated to avoid actual declines in the outcomes of the higher group as it is shrunk towards the average. Another reason why gender convergence is specified in terms of levels rather than rates is that if the lagging unit is actually expanding more rapidly, strong convergence in rates actually *delays* convergence in levels. In principle, this applies equally to cross-country convergence, however it is a greater concern with respect to gender convergence because: a) the above situation is very common (female education often lags behind, but is actually growing faster), and b) the assumed convergence is stronger.

The third adjustment is straightforward, and consists of ensuring that the fact that the different education levels are extrapolated independently does not result in impossible ‘cross-overs’ during the

projection horizon. In other words, the share attaining a lower, prerequisite level, is made to equal at least the share attaining the level(s) above.

Finally, we impose a ceiling of 90 percent on the share attaining post-secondary or tertiary education, to account for the fact that we do not necessarily expect this level to become fully universal at any point, reflecting limits on both the demand for graduates and the ability to take advantage of such advanced education. The precise ceiling is somewhat arbitrary, but reflects the fact that in the most advanced countries, post-secondary participation is already approaching 80 percent. A ceiling much below 90 percent would therefore require a very sudden expansion stop, or even the baseless assumption that this current levels already represent an ‘overshoot’. In principle, an attempt could be made to *estimate* the saturation level. However, for post-secondary, the vast majority of observations are well below the inflection point of the s-curve of expansion. Estimating the maximum level on these data would require excessive confidence in the accuracy of the functional specification. A prior could be put on the saturation level, so that, effectively, some runs would converge to a ceiling of 90 percent, others to 95 or 85 percent, for example. However, again this would then be transformed to a posterior that based on data that may not actually be informative. The alternative is to add uncertainty to the ceiling post-hoc, but doing so would risk ‘over-engineering’ this adjustment.

For consistency, the last two adjustments mentioned, i.e. enforcing the hierarchical constraint between education levels and the 90 percent ceiling on post-secondary and tertiary attainment, were similarly applied to COM-BMK at the Commission’s request.

2.2.2 WIC Universal Upper Secondary (WIC-SDG) scenario

Overview

For the WIC-SDG scenario, the above forward projection approach underlying WIC-GET is modified such that the projected trajectories for upper secondary attainment reach at least 97 percent by 2030. The start of the trend break is adjusted by attainment level, since the cohort aged 15-19 in 2010, for example, will already eventually benefit from increased post-secondary participation during the period 2015-2030. Conversely, changes starting in 2015 were largely too late to affect the primary attainment of those already aged 15-19 in 2020. In addition, the target scenarios make explicit that accelerating expansion at one level of the education system will not leave other levels unaffected. In particular, some degree of ‘spill-over’ to the levels above is to be expected, and is included in the model.

Details

Trend Break In reality, the transition onto a new, target-achieving, trajectory would be expected to occur gradually. While in general it would be feasible to ‘phase in’ a new drift, in the case of the SDGs, with a target horizon of only 15 years, any trajectory actually reaching the target will have to reach full speed sufficiently rapidly so that in terms of 5-year time steps it can be treated as applying immediately.

Spill-over effects between education levels The spillover effect is modelled by exposing the attainment level above the target level, and the level above that (if any), to an increase in trend drift (at the transformed scale) that is 50 percent respectively 10 percent as large as required at the target level to meet the target.

This can be interpreted as an approximation to cutting the log-odds ratio of transitioning from secondary to post-secondary of the target relative to trend scenario in half for the ‘additional’ secondary

school graduates under the target-achieving trend, and maintaining those new odds into the future. If the model were specified in terms of a logit curve instead of a probit curve, this interpretation would be exact. Parenthetically, as already mentioned above, the reason the model is in fact specified in terms of probits is because this extends more naturally to model elaborations where an underlying Gaussian latent propensity for education is assumed at the individual level. Also recall the preceding discussion concerning the ceiling for post-secondary attainment that maintaining constant transition rates from secondary to post-secondary are not an attractive alternative, because they would imply limiting ultimate post-secondary participation to the level of the current transition rate.

The amount of 50 percent spill-over at the transformed scale was chosen for substantive reasons: there is no reason to expect a targeted boost at one level would actually increase growth at the level above more than the target level itself (suggesting the spill-over should remain below 100 percent), but it seems plausible to expect some upward pressure on post-secondary participation if the pool of eligible upper secondary graduates increases. The reason the spill-over is not specified proportionally to the transition rate from secondary to post-secondary is that doing so would cap a country's long-term participation in post-secondary at the level of the current transition rate, which will often be unreasonably low. If the current transition rate from secondary to post-secondary is 30 percent, for example, and this were held constant, then universal upper secondary attainment would imply merely 30 percent participation at post-secondary, and no further growth or convergence with other countries.

In principle, an attempt could be made to utilise estimated correlations between the drifts at different levels in order to 'endogenise' the amount of spill-over. However, since each country only has *one* past secondary drift and post-secondary drift, these can only be correlated across *sets of countries*. But the spill-over effect will strongly depend on context, and questions such as whether funding for secondary expansion comes at the expense of funding for the post-secondary sector or not. It is not at all clear what the appropriate contextual country sets in terms of spill-over behaviour would be. More importantly, it is clear that the additional secondary expansion associated with a focused effort to universalise that level would be qualitatively different from the past general trend and would not at all represent "business as usual". It is therefore questionable whether the past association between levels could sensibly be extrapolated. It seems preferable, therefore, to make the simple, but transparent, assumptions discussed at the beginning of this section.

As a side note, the same argument explains why there are no secular period effects ('year dummies') included in the model: It is not at all clear that such positive or negative shocks affecting all countries in a single five-year period even exist. This would beg the question whether period effects should not rather be defined at the regional level, for example. At worst, there is a loss of efficiency, as correlation between the idiosyncratic country shocks is not exploited in the estimation. However, from this perspective also, there is no clear reason to expect period effects to be the most important source of such correlation.

Target-setting in a probabilistic framework While it would be possible to deterministically calculate the necessary additional drift to reach a given point target level, doing so would be a lost opportunity to gain additional insight. Instead, SDG targets are treated as "future observations". Specifically, they enter the likelihood by specifying that the drift resulting in the overall upward trend is allowed to increase by whatever amount necessary (with an effectively flat prior) to reach the target, starting in 2015.

Note that this specification of the target scenarios means the target of 97 percent is typically exceeded, not just barely met, in contrast to a typical 'target-achieving path' interpolated deterministically. This behaviour is desired and deliberate. Intuitively, assuming a country did meet the targets, these tra-

jectories represent typical paths of having got there. Retrospectively, the set of countries that meet the targets will have exceeded them on average, given their lack of perfectly exact control over the outcome. An analogy will clarify this: if we invite a group of runners to attempt to run 100 m in 11 s, then the successful group will clearly have taken less than 11 s on average. Since in addition, the target scenarios have the same probabilistic nature as the trend scenario, they allow for arbitrary conditioning. Examples of such conditional perspectives include questions related to the probability of different countries meeting fixed targets by a certain time, to complement the more conventional question of the probability of exceeding certain participation levels in a fixed year. While this is fully analysed elsewhere, for present purposes we focus on the ‘minimal’ target path traced out by the cross-sectional 0.01 quantile of the target paths that only just reaches the SDG target. In addition to sharing their probabilistic nature, just like the trend scenario, the target scenarios incorporate the nonlinearity of educational expansion as it really occurs. In particular, this includes the likely deceleration of expansion as universal participation is approached, as well as the fact that countries that meet the targets will necessarily have “overshot”, on average. This allows us to quantify the risk of failure associated with attempting to monitor whether countries are ‘on track’ according to simple linear plans.

A second subtlety created by the desire to estimate target-driven scenarios probabilistically within a Bayesian setting deserves additional attention. Recall that the proposed set-up corresponds to treating the target as a ‘future observation’, and effectively selecting target-achieving trajectories by conditioning on the target being achieved. One implication is that, even though these trajectories may make use of a trend-break, the *historical trend* may also be estimated differently in the target scenario. Technically, this is, of course, perfectly correct. By conditioning on target-achievement, we are effectively answering the question: supposing the target is reached, how did we get there? And it is indeed both correct and statistically intuitive that among universes where Thailand, say, reaches universal secondary participation by 2030, those will be over-represented where, historically, Thailand actually has a higher ‘intrinsic’ expansion rate than historical evidence suggests, and it has to date been underperforming relative to its capabilities. However correct it may be, this implication creates a communication problem, since it is likely to be considered counter-intuitive by a policy audience that the inclusion of a fictitious target should affect our estimates of *historical* dynamics.

This problem is avoided here simply by putting a uniform prior on the amount of trend acceleration, so that it does not affect the marginal distributions of historical parameters. This approach at the same time solves another problem. If acceleration were not ‘free’ in likelihood terms, the estimation of the random shocks would inevitably be estimated upwards. In words, the results would be shifted towards considering part of the target-attainment to be literally due to luck. The fact that under the current set-up, this effect is avoided, at the same time creates the technical convenience of being able to use the very same simulated sequence of future shocks for different scenarios. Otherwise, doing so would risk creating a spurious upward ‘spike’ in 2030 even in the ‘business-as-usual’ trend trajectory.

2.2.3 WIC Universal Lower Secondary (WIC-ULS) scenario

Overview

It is possible to imagine a WIC-BMK scenario that mirrors the COM-BMK scenario, in that all countries are assumed to move onto a common trend in 2015 that is defined as the average trend of the historically 25 percent most rapidly expanding education systems. While this captures the *intent* of the COM-BMK scenario, the results inevitably differ, for several reasons. Firstly, the underlying data is different, with slightly different country coverage, and series that are longer in time (going back some 50 years, rather than 10–15), but in 5-year time steps and less current. Secondly, as already discussed, trends and country rankings in terms of ultimate educational attainment may differ

from those in terms of enrolment. Thirdly, the benchmark trend is imposed as an adjustment to the WIC-GET scenario, meaning the results still reflect the impact of the adjustments mentioned in the preceding section (e.g. gender convergence) as applied to the original country-specific trends. Fourthly, there is a minor technical difference in that COM-BMK is effectively defined on a logit scale (see above), whereas such a WIC-BMK would be defined on a probit scale.

Comparing such a parallel implementation of the benchmarking narrative would be worthwhile on its own terms. As a matter of fact, such a scenario was indeed calculated, in order to generate appropriate interpolation weights for the attainment levels without corresponding enrolment indicators in the Commission scenarios. However, in order to maintain a manageable number of scenarios in the presentation that *differ* from each other in meaningful ways, we instead analyse a ‘partial progress’ scenario derived from the attainment model that follows an alternative logic. Whereas COM-BMK implies that expansion across all education levels is accelerated, but progress towards universalisation is incomplete, the scenario WIC-ULS encodes the assumption that universalisation is indeed achieved by 2030, but at a lower level, namely *lower* secondary rather than upper secondary. As a result, in WIC-ULS, lack of schooling is eliminated entirely, but progress at higher levels is limited, whereas under COM-BMK progress at all levels, including upper secondary and tertiary, accelerates significantly, but at the same time there may remain significant numbers of children with very limited schooling. The discussion further below shows that these two different ways of conceptualising the notion of ‘partial progress’ towards SDG 4 can indeed lead to different results.

A separate detailed discussion of WIC-ULS is unnecessary: its specification is entirely parallel to WIC-SDG described comprehensively above, the sole difference being that the target for 2030 is specified at the lower secondary level. One implication is that the ‘spillover’ effect described above now concerns upper secondary. Its form remains the same, that is, the ‘additional’ lower secondary attainers relative to the baseline trend are assumed to face log-odds of progressing to upper secondary that are cut approximately in half relative to the odds estimated on the trend. Unlike the previous case of WIC-SDG, there is now also a level *two* steps above the level at which the target is specified. To account for this ‘second-order spillover’, the log-odds of progressing to post-secondary or tertiary for the additional lower secondary graduates is reduced to approximately 10 percent of the past value. As above, the interpretation in terms of log-odds would be exact if the underlying model were logistic, but is still approximately correct given the actual probit specification.

3 Projections of development impacts

It is known that education has strong linkages with virtually all other dimensions of sustainable development, both direct and indirect. Most (though not all) of these are positive reinforcements. Accordingly, trajectories of educational progress towards the SDG's education targets are not only of interest on their own terms, but also in terms of their implications for other development outcomes.

For each education scenario, the output of the multistate human capital projection model consists of age-sex-attainment structured population profiles at the country level. For the following impact projections, these feed into various independent quantitative models describing the relationship between human capital and other development outcomes. With a single exception (disaster deaths), these models take full advantage of the age-sex-attainment disaggregation. In other words, this allows for *differential contributions of each education group in the population, rather than an aggregate education index* such as the mean years of schooling. For example, children of women with secondary schooling are exposed to a different individual probability of premature death than the children of women with only primary schooling, and individuals with post-secondary or tertiary education make a different contribution to the national economy than individuals with only secondary schooling.

The fact that the intermediate human capital project output is 'generic' in the sense that it resembles empirical human capital *data*, only for future time periods, means it can be used as input in arbitrary 'downstream' estimates. While precluding feedback effects, this approach enables the use of well-established models by others. An example in the present exercise is provided by the projections of extreme poverty, which take advantage of existing poverty-growth elasticities estimated previously at the World Bank. The domain-specific models of the relationship between education and these outcomes are discussed in the respective sections that follow.

The previous section described in detail the definition specifically of the education component of the human capital projection scenarios. Numerous other assumptions are required to fully specify such a scenario, notably fertility and mortality assumptions. In the present modelling exercise, all these parameters besides education itself are identical to the 'medium' baseline scenario of the current Wittgenstein Centre human capital projections as documented in Lutz et al. (2014), which is itself essentially equivalent to the 'middle of the road' Shared Socioeconomic Pathways (SSP) scenario, i.e. SSP2, that underlies the modelling of the international climate research community, including the models for the Intergovernmental Panel on Climate Change (IPCC).

Facilitating interpretation, *this approach isolates the potential contribution of educational expansion specifically.* In other words, the aim is not to generate a 'best guess' integrated projection for the outcome measures, but to illustrate the extent to which their development is potentially influenced by education. This applies even to the WIC-SDG scenario. While the Wittgenstein Centre has defined SDG-inspired sets of assumptions for fertility, health, and mortality for other purposes, for the present report only education is assumed to follow an SDG trajectory, with other development dimensions remaining on their assumed baseline trajectory, in order to isolate the impact of the education assumptions.

Unfortunately, not all development dimensions are equally suited to be analysed from the perspective of the potential contribution of educational expansion. Firstly, goals and targets associated with well-defined indicators are required for a quantitative model of the relationship with educational attainment. Secondly, the existence of strong theoretical arguments and evidence for a relationship with education makes for more meaningful analyses, and takes us closer to a causal interpretation. Thirdly, there must be some amount of historic data on which the quantitative *strength* of the relationship with education can be estimated. Finally, in supporting the overall argument that education

is strongly-connected within the ‘network’ of SDG interactions, it is desirable to model outcomes drawn from different dimensions of sustainable development.

These criteria justify the selection of the following outcomes. Two of these, namely health and economics, are areas where the effect of education is well-known. The third, disaster vulnerability, is an area where a strong relationship with education can be identified, but there remains little understood among actors in that field. Specifically, in the following we present model results for how infant and child mortality (relating to SDG 3.2), specifically survival to age 5, differs according to education scenario, as well as adult life expectancy (reflecting SDGs 3.3 and 3.4). In the economic dimension, we do the same for aggregate national economic growth (relating to SDGs 8.1 and 8.2), the absolute extreme poverty headcount rate (SDG 1.1), and — more tentatively — the relative position of the ‘bottom 40 percent’ (SDG 10.1). Finally, we move to modelling disaster deaths (relating to SDGs 1.5, 13.1, and 11.5).

3.1 Health

Health is a crucial dimension of sustainable development, and health goals are prominent among the SDGs. In addition, the relationship between education and health is known to be robust, and is relatively well-studied. This is reflected in the fact that, unlike the link with economic outcomes and disaster vulnerability discussed further below, mortality differentials by education are an intrinsic component our population projections, rather than being modeled post-hoc. Accordingly, the differences in the simulated outcomes include interactions such as the fact that the education-induced improvements in average under-5-mortality are attenuated by lower average fertility of the more educated mothers. The exact assumptions included in the model, and the evidence based on which they rest, are fully documented in Lutz et al. (2014). Note that a general SDG population scenario would take into account the implications of the health goals, for instance. Here, the ‘SDG scenario’ deliberately maintains existing trend assumptions for fertility and mortality, in order to isolate the potential contribution of educational expansion.

With infant and child mortality in mind, we first examine how the education profile of women of prime child-bearing age develops over time under the progress scenarios for education compared to the trend Fig. 1. As mentioned, the education profiles of *mothers* is likely to improve less rapidly, due to the higher average fertility of the less-educated. However, there is also some evidence that child health also benefits from community-level effects and the general diffusion of healthy practices and behaviours. Such effects in turn would suggest that the benefits would be greater than suggested by the changing education distribution of individual women.

Several important observations can be made. Most of the differences between the different scenarios occur at the lower end of the income distribution. For high income countries, that are mostly already on a trajectory towards universal upper secondary education, the differences implied by the scenarios are marginal. Mostly this is also true for upper middle income countries, with the exception of the full SDG scenario, which by definition leaves only a residual share of less than upper secondary attainment. With reference to the lower middle income countries, the aforementioned difficulty of treating gross tertiary enrollment as a proxy for post-secondary and tertiary attainment is highlighted: the main distinction here appears between the enrolment-derived Commission scenarios and the attainment-derived Wittgenstein Centre scenarios, with the former suggesting far higher levels of tertiary attainment. So much higher, in fact, that the ‘feasible progress’ Commission benchmark scenario in some ways *exceeds* the Wittgenstein Centre scenario of achieving universal upper secondary schooling outright. For these countries, the differences due to the underlying data source are larger than those between trend and progress scenarios. This is not true for the low income

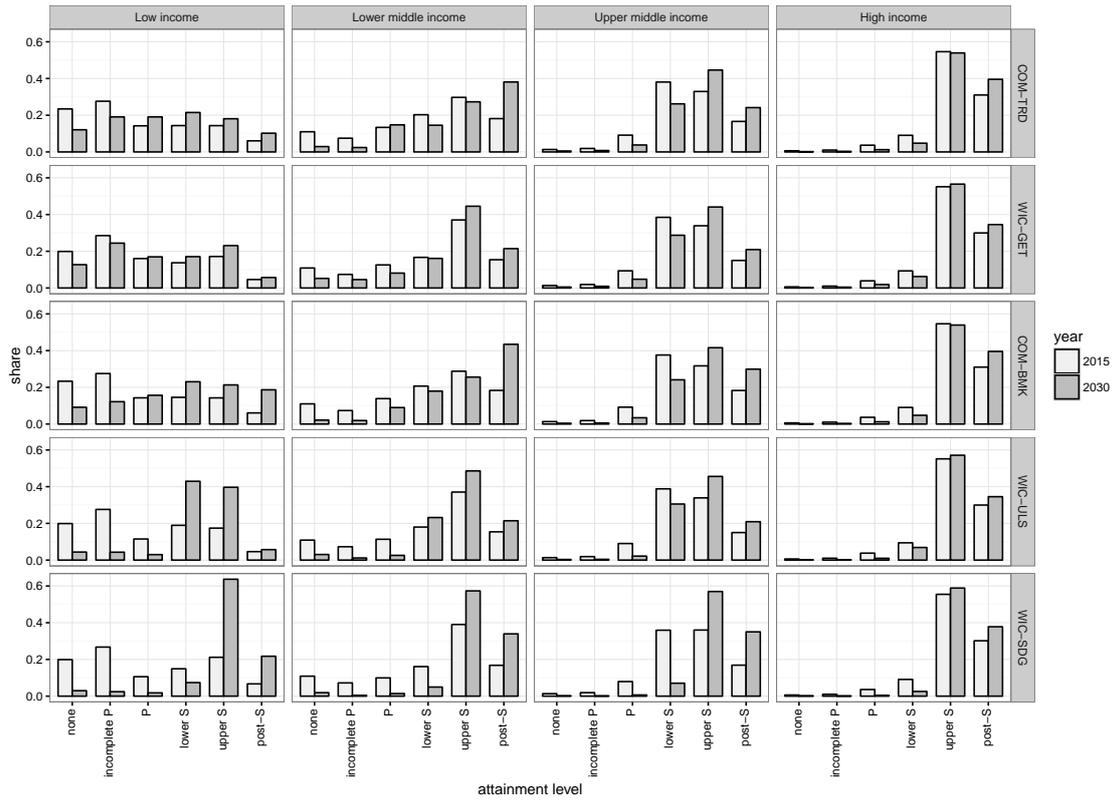


Figure 1: Change in attainment profile of females aged 20–29 over time.

countries. Here, we see that the two trend scenarios are fairly similar (albeit still with greater tertiary gains in the Commission’s version), but that the various progress scenarios lead to quite different outcomes. It is also evident that the two partial progress scenarios COM-BMK and WIC-ULS do not stand in a hierarchical relationship, but are qualitatively different: while the former implies far greater expansion at the highest level, the latter more thoroughly reduces low attainment. This is an important observation to bear in mind as we turn to the projections on child mortality.

In terms of the outcomes in the form of non-survival to age 5, fig. 2 displays the estimated impacts by 2040. The later ‘SDG cohorts’ who complete their schooling close to 2030 will have most of their children some time after that. The comparison of the Wittgenstein Centre scenarios suggests that the benefits of universal lower secondary schooling are roughly half of those of universal upper secondary either. Achieving either can be expected to make a meaningful contribution to reducing infant and child mortality. The projected contribution of the Commission’s progress scenario relative to its baseline under the same education-specific rates is somewhat smaller. This reflects the fact, highlighted above, that COM-BMK implies less progress at low levels of education and more progress at the post-secondary and tertiary level, but that in terms of child mortality, reducing low schooling is more gainful.

Since the high-mortality settings that are our greatest concern, fig. 3 shows the trajectories for the two lower income groups in greater detail, and in terms of relative changes compared to the baseline in 2015. Up to 10 percentage points in the drop of under-5-mortality may be added by achieving the SDG education target of universal upper secondary schooling, even by 2030, before all the beneficiaries have actually begun their childbearing. Moreover, in low income settings, the decline in child mortality may well begin to slow down in the absence of additional educational expansion.

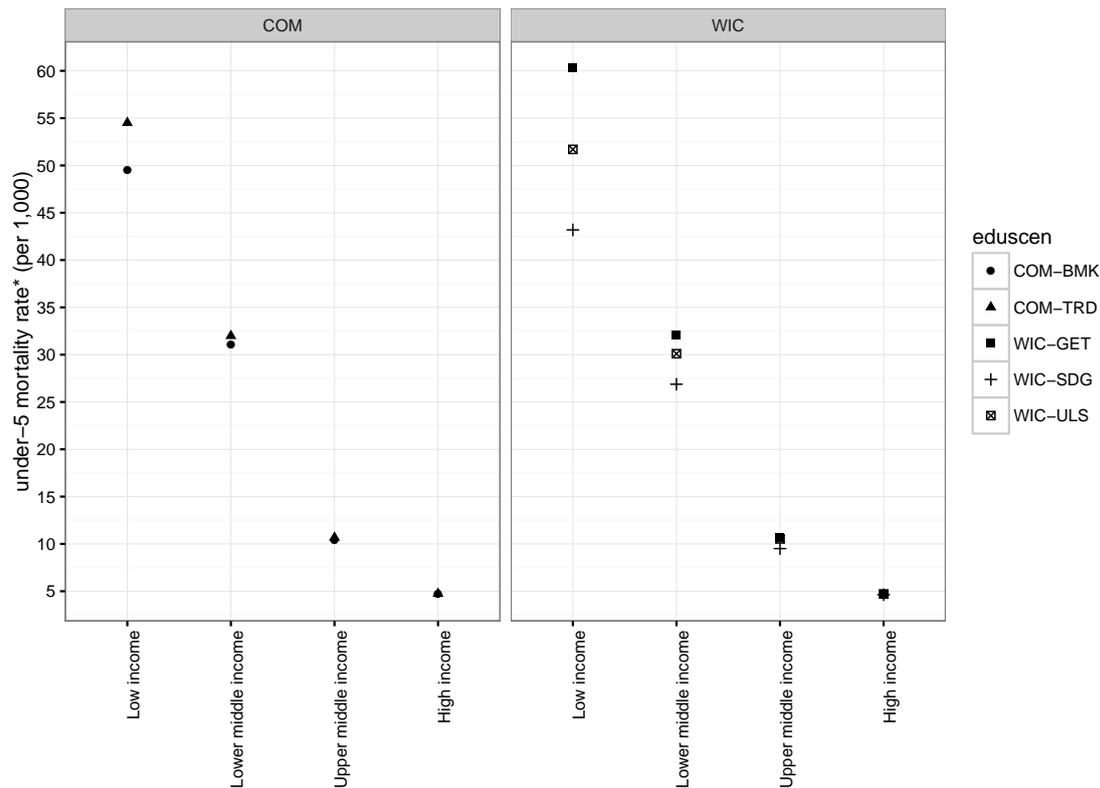


Figure 2: Under-5 mortality by region and scenario.

While these effects may be considered to be only moderate, it is important to note that they represent the differences between progress scenarios and a baseline that in itself assumes quite significant educational expansion based on existing trends.

A direct comparison with the estimates of the historical contribution of education to declining child mortality of Gakidou et al. (2010) is not possible, because their analysis concerns years of schooling rather than attainment, and is benchmarked against *no* educational improvement. With these caveats in mind, the additional benefit of the SDG scenario over and above prevailing trends estimated here for low income countries is similar in magnitude to the contribution of educational expansion during the period 1990 to 2010 estimated by Gakidou et al., at around 15 per 1,000 child deaths less.

In terms of the potential contribution of progress towards universal secondary education to improving *adult* health, fig. 4 displays modelled trajectories of average remaining life-expectancy at age 15 in low income countries. For higher income countries the impact is marginal. Despite significant differences in attainment-specific life expectancy even in high income countries, it is unsurprising that the change to overall life expectancy is very modest, given the relatively short time horizon and modest increases to the stock of total population attainment. Even in the low income country group shown here, the cohorts benefitting from the progress scenarios have not reached ages of high mortality by 2040. Extending the time horizon further does not provide additional insight, because in the very long run, convergence assumptions drown out most of the education differentials.

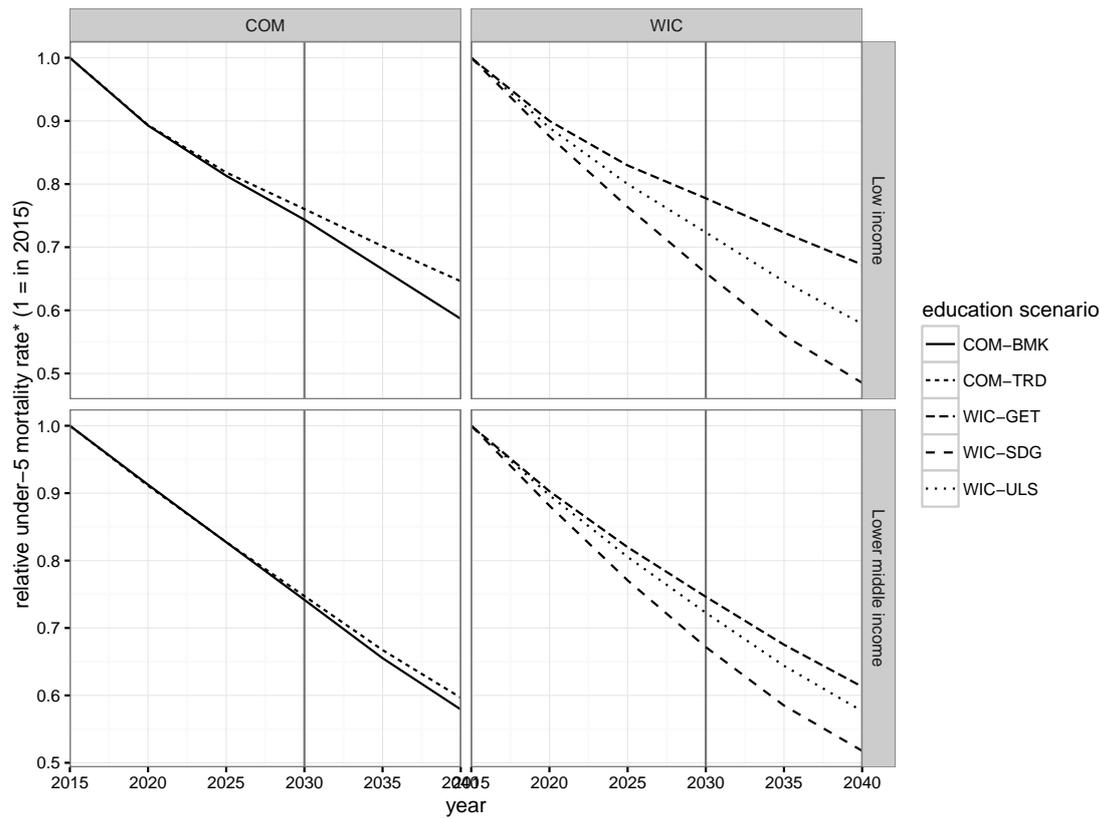


Figure 3: Under-5 mortality over time for highest-mortality regions.

3.2 Economic growth and poverty reduction

The economic effects of human capital expansion are among the most widely-studied. However, only relatively recently has this literature become sufficiently sensitive to the importance of accounting for age structure in determining the expected economic benefits of educational expansion. Of particular interest in light of the SDG goals, and also in terms of readily-available models which can be applied to our education scenarios, are aggregate economic growth, and extreme ‘dollar a day’ poverty (currently defined as USD 1.25 at 2005 PPP, or equivalently at USD 1.9 in 2011 PPP).

In the following, national income projections are obtained using the model by Crespo Cuaresma (2015). The income projection framework combines population projections by age and educational attainment level with an aggregate production function estimated using historical data. Human capital dynamics are assumed to have two distinct effects on income per capita. On the one hand, improvements in educational attainment affect labour productivity. On the other hand, total factor productivity is also affected by human capital through its effect on technology creation and adoption. The results of applying this model to the present education scenarios are shown in fig. 5. While the main scale is in logged GDP per capita relative to its level in the year 2000, the difference in 2040 between the Commission trend and progress scenarios is additionally translated into straightforward percentages.

Because the individuals benefitting from educational expansion during the period 2015–2030 have to enter the labour force in significant numbers before being able to make much of an impact, it is unsurprising that meaningful growth effects are delayed until long after the SDG target year of 2030. Indeed, in high and upper-middle income countries, the additional growth expected from acceler-

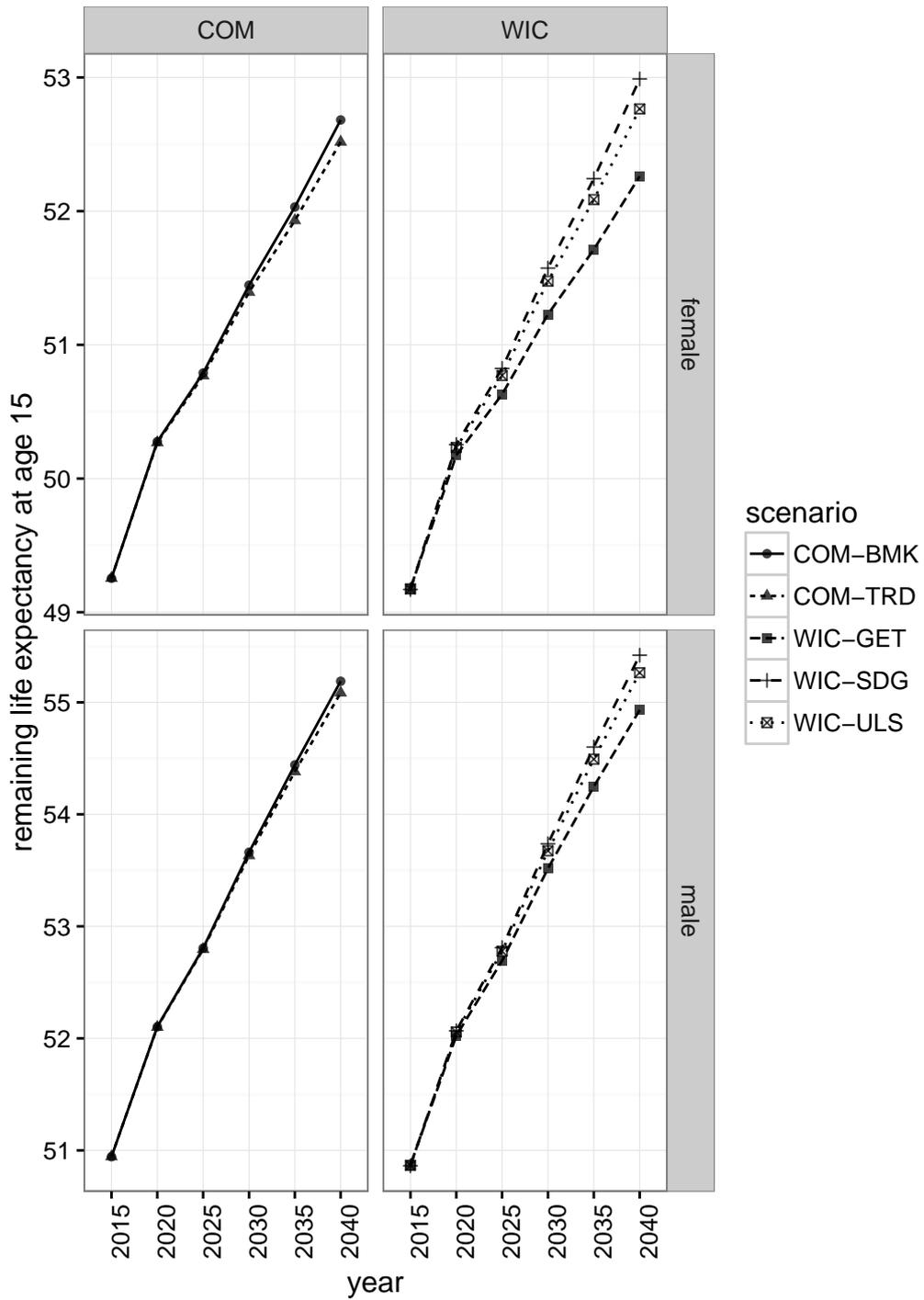


Figure 4: Projected adult life expectancy (remaining life expectancy at age 15) by scenario, un-weighted average across low-income countries.

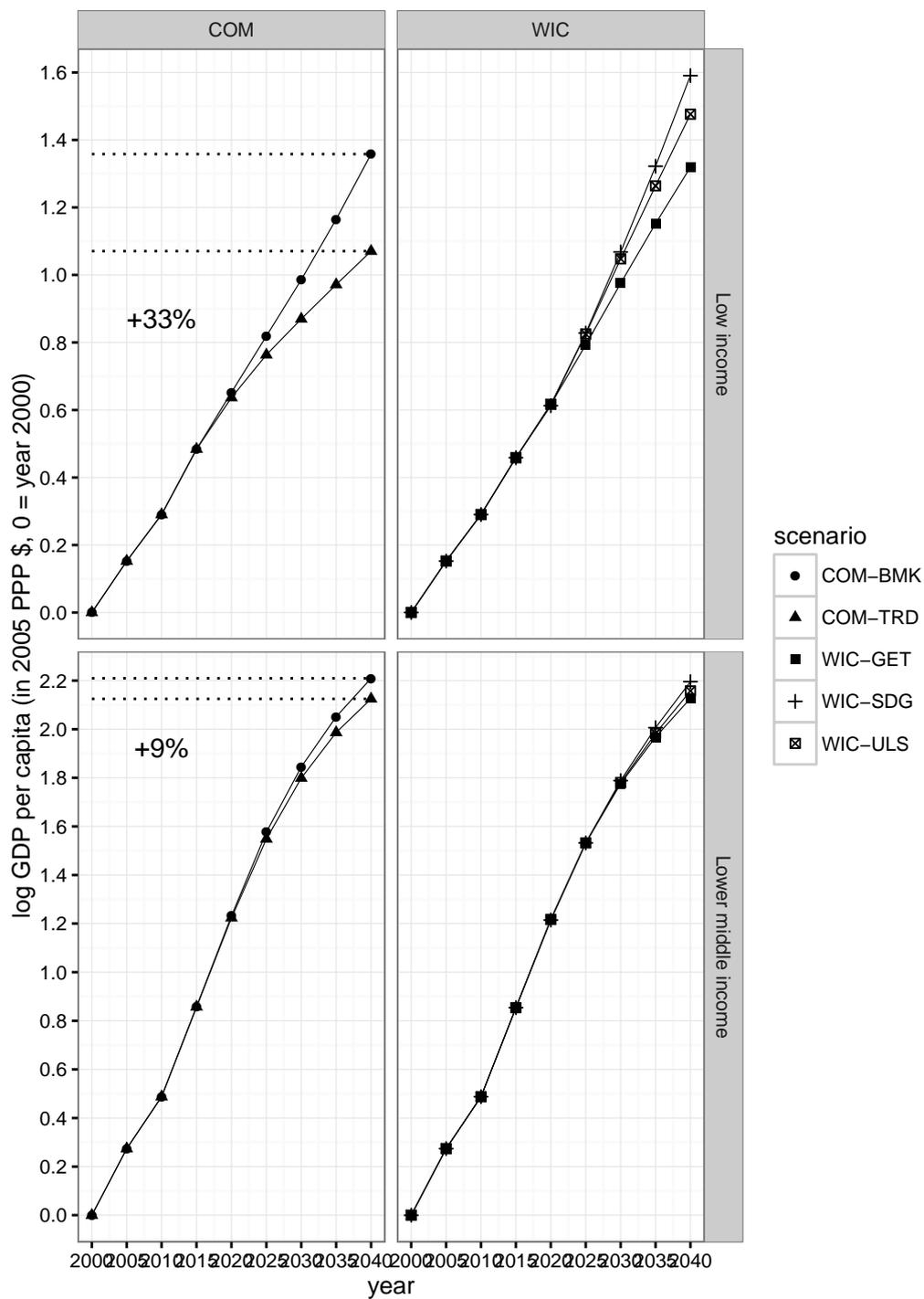


Figure 5: Projected GDP growth by scenario.

ated secondary school expansion is minimal (and hence not even shown). Not because education does not matter, but because many of these countries anyhow have high and increasing levels of secondary participation even under the trend scenario, so that the additional effect is at most marginal.

This plays out rather differently in low-income countries. While universalising upper secondary education would in principle be expected to make a large difference to their growth prospects in the long run, these countries are of course also farthest from realising this goal. Comparing the Commission and Wittgenstein Centre scenarios, the latter can be seen to be more 'bullish' overall, but that the former attribute a greater difference to accelerated expansion. Even this difference is relatively modest, but again, this understates the contribution of educational expansion as such, because significant educational growth is expected even under the trend scenario that provides the baseline here.

Arguably of greater importance than overall economic growth is the goal of poverty reduction. Poverty impacts here are approximated by combining the growth rates of the above model to with the economic growth elasticities for poverty obtained by Ravallion (2012, AER). The underlying assumption is that (mean) income per capita growth leads to poverty reduction, but that poverty itself has an effect on the elasticity of poverty to economic growth. This implies that econometric models for poverty change should include an interaction term of (lagged) poverty and income growth in addition to the standard income per capita growth variable. The results are shown in fig. 6. Only the lowest two income groups are shown here, because 'dollar a day' poverty is rare in higher income countries almost by definition.

Given the tight link in the model between economic growth and absolute poverty, the overall pattern is similar as above. In other words, the baseline trend under the Wittgenstein Centre scenarios is more optimistic, but the contribution of the progress scenario is smaller.

Assuming the overall pattern stays the same, it seems that while accelerated educational expansion can be expected to make a sizeable contribution to overall growth, given the lag time, the education SDG might be 'too late' to contribute much to eliminating extreme poverty in terms of an absolute threshold, other than in the very poorest and currently least-educated countries. Even there, educational expansion and its contribution to growth is insufficient to 'eliminate' extreme poverty by 2030.

To put these results into perspective, however, note that by 2030, the current absolute extreme poverty threshold will become increasingly irrelevant, and the question whether accelerated educational expansion can still contribute to raising large numbers of people to higher income levels becomes increasingly important. Indeed, the current target can be criticised as far too minimalist, as living on even two or three dollars a day amounts to dire poverty, all the more so by 2030 when average incomes are likely to have increased substantially (even in today's dollars). Estimating the effect on arbitrary poverty thresholds would, unfortunately, no longer be able to draw on the existing published research on the elasticities between growth and the current threshold.

3.3 Disaster deaths

There are strong linkages between education and climate change. On the one hand, this concerns both the ambivalent relationship between higher education and higher incomes and consumption, that potentially increase emissions overall, even if the more educated may be more supportive of institutional reforms and interventions aimed at climate change mitigation. On the other hand, there is evidence that higher education levels make a positive contribution to reducing vulnerability and increasing resilience to natural disasters generally.

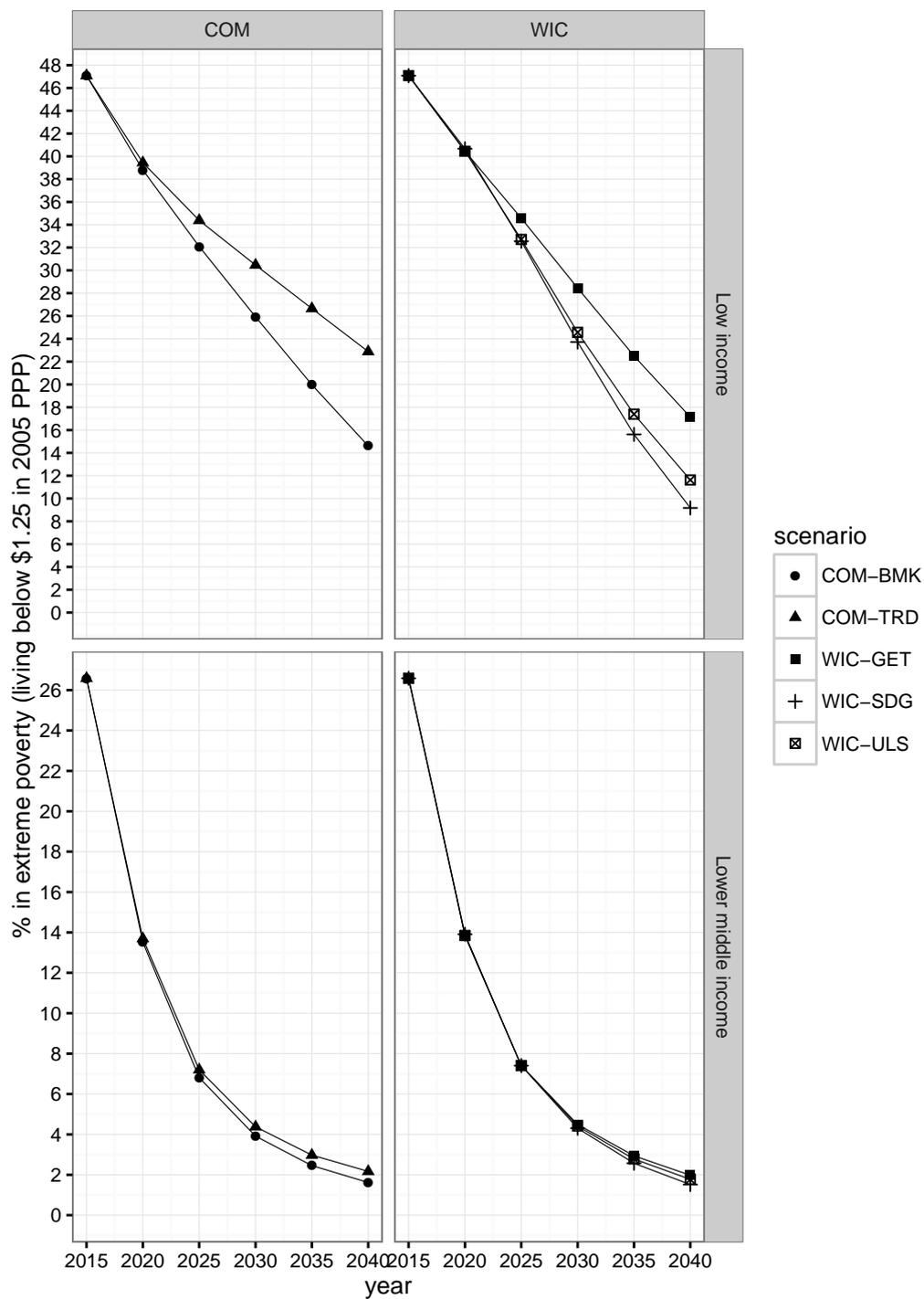


Figure 6: Projected absolute extreme poverty by scenario.

While there is a notion that natural disasters strike ‘indiscriminately’, this contradicts the basic assumption underlying Disaster Risk Reduction, namely that information and preparedness can make a difference to survival and/or loss of assets and livelihoods. Unfortunately, information on educational characteristics of affected populations is often not collected in disaster-response situations. However, where it is available, the data suggest that the more educated do indeed tend to exhibit a greater awareness of risks, of appropriate preparation and response, and suffer smaller average losses in case of actual disaster. This justifies the expectation that vulnerability vis-a-vis climate-change induced disasters in the future may benefit similarly. This is of particular interest because ‘combating climate change and its impacts’ is an important addition to the SDG agenda in comparison to previous development frameworks, and because this topic is among the least-well studied.

The potential positive contribution of education (and future educational expansion) to reducing vulnerability to climate disasters has been found both at the micro-level and in aggregate data. The following model and the study on which it is based fall in the latter category. Nevertheless, the fact that the findings fit well with corresponding micro-level evidence, and that the causal mechanisms outlined above are plausible, it may serve to at least illustrate the potential magnitude of the contribution education can make.

In this simulation, the predicted decadal numbers of deaths from natural catastrophes (storms, floods, droughts, landslides, and extreme temperature events) are obtained from the model presented in Lutz et al. (2014). This model uses past information on the relationship between human capital and disaster deaths (as available from the Emergency Events Database (EM-DAT 2010)) controlling for other relevant covariates to project the impact of climate change in terms of future vulnerability according to the different Shared Socioeconomic Pathways (SSP). For the present purposes, the progress scenarios were simply added as another narrative of future adaptive capacity to the set of SSPs and several different scenarios were calculated for future environmental hazard. In the first scenario, the future number of disasters experienced within a country over a decade was assumed to remain what it was during the 2000-2010 period over the entire 21st century. This is then contrasted with a climate change scenarios assuming a 20 percent increase in the decadal number of disasters in comparison to the previous decade, respectively. The uncertainty ranges around the predictions indicate 95 percent confidence intervals.

This figure is obtained from the panel regression model with time fixed effects predicting the log of disaster deaths by climate-related disasters i.e. hydro-meteorological hazards such as floods, droughts, storms and extreme temperature. The estimated results are then transformed into predicted number of disaster deaths (measured as the logged number of deaths per million of population) according to different socioeconomic development pathways (SSPs) which are highly relevant for population dynamics and composition, and different climate change scenarios. For climate change scenarios, we make an assumption of an increase in hydro-meteorological extreme events of an average 10% and 20% per decade respectively. Although this is a rather simple assumption, even among the climate modelling community, there has not yet been a consensus on how climate change-induced extreme weather events would look like (Schleussner et al. 2015). However, the IPCC report and other scientific papers have confirmed that the current increase in the frequency, intensity and severity of extreme climate events observed today is due to anthropogenic climate change and these events are likely to rise in the future. The IPCC is particularly highly certain about the increase of longer and/or more intense heat waves, heavy precipitation events and increased incidence and/or magnitude of extreme high sea level (IPCC 2014).

The strength of the estimated linkage with education is sizeable relative to the overall prediction range for a given climate scenario. For example, the median predicted outcome in 2040 under the SDG education scenario is close to the lower 2.5 percentile under the trend scenario. In absolute terms,

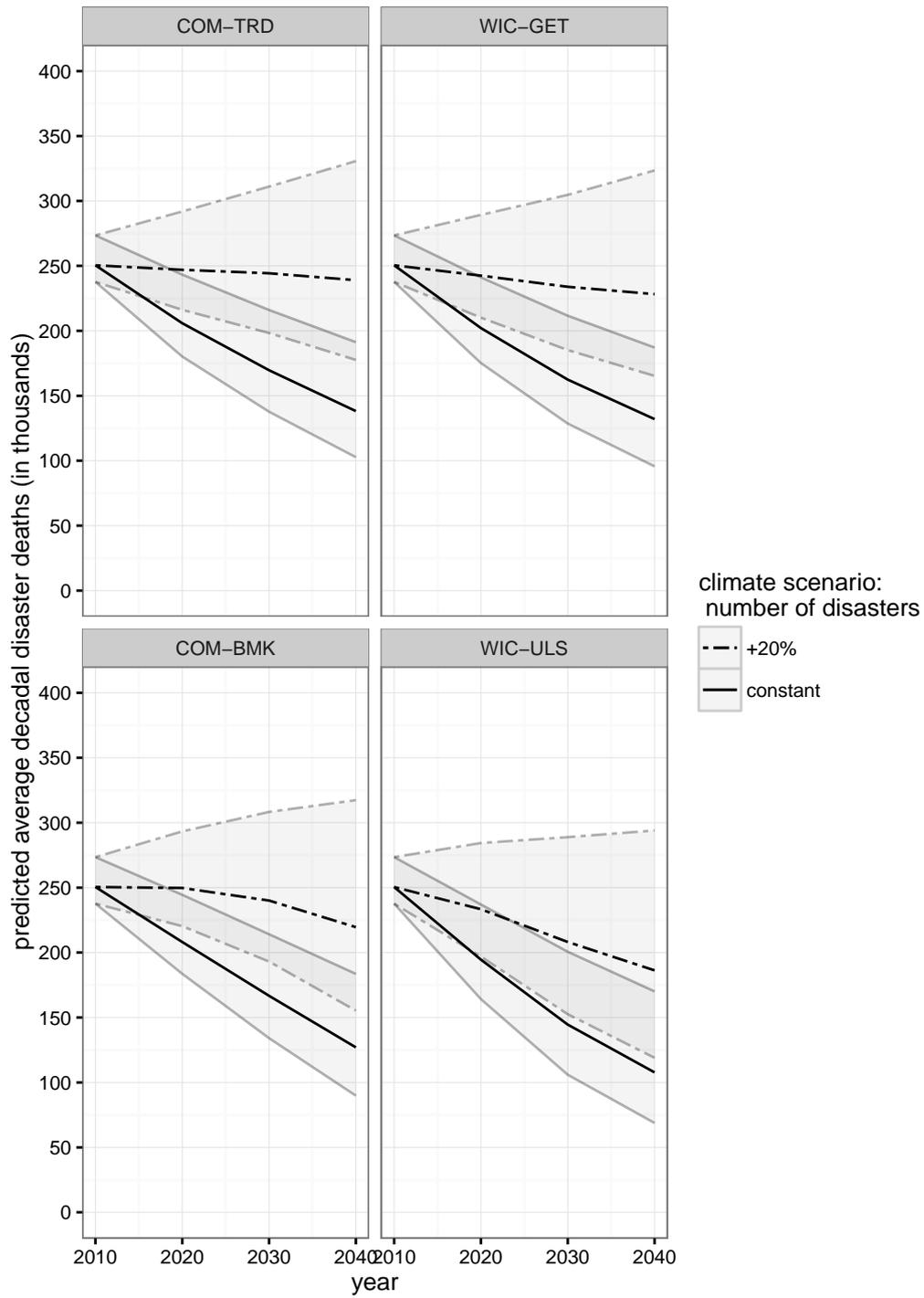


Figure 7: Projected decadal deaths from hydro-meteorological disasters by scenario.

the predicted number of decadal disaster deaths is some 10–20 thousand lower under the progress education scenarios in the medium term, at constant disaster frequency and severity. Under a climate change scenario of more frequent disasters, the difference between the education scenarios widens to roughly twice that range.

From the perspective of the potential contribution of educational expansion to *off-setting* climate change with respect to its disaster toll, note that even under the more severe climate change scenario, baseline educational expansion may contribute to keeping the actual number of disaster deaths approximately constant well into the second half of the century. Accelerated educational expansion could even keep the predicted value under the severe climate change scenario within the expected range under a no-change climate scenario until 2040 or so.

In this particular study, the effect of education is modeled as a coefficient on the share of the adult population with at least lower secondary education. Accordingly, among the Wittgenstein Centre scenarios WIC-SDG and WIC-ULS essentially coincide in this case. Only the latter is shown, therefore. This specification also explains the less optimistic results under the Commission scenarios, which result in larger gains at the top of the education distribution, but leave a larger share below lower secondary attainment.

In terms of regional variation, because these are absolute numbers of deaths, the global pattern is strongly dominated by the experience of Asia, which is not only home to some of the largest populations, especially coastal, but at the same time the locus of many disasters.

References

- Cuaresma, J. C. (2015). Income projections for climate change research: A framework based on human capital dynamics. *Global Environmental Change*, page (online first). doi:10.1016/j.gloenvcha.2015.02.012
- EM-DAT, CRED. 2010. “The OFDA/CRED International Disaster Database.” Brussels: Université Catholique de Louvain, Center for Research on the Epidemiology of Disasters (CRED). <http://www.em-dat.net>.
- Gakidou, E, Cowling, K., Lozano, R., and Murray C.J. 2010. “Increased Educational Attainment and Its Effect on Child Mortality in 175 Countries Between 1970 and 2009: a Systematic Analysis” 376 (9745): 959–74. doi:10.1016/s0140-6736(10)61257-3.
- Lutz, Wolfgang, Raya Muttarak, and Erich Striessnig. 2014. “Universal Education Is Key to Enhanced Climate Adaptation.” *Science* 346 (6213): 1061–62. doi:10.1126/science.1257975.
- Ravallion, Martin. 2012. “Why Don’t We See Poverty Convergence?.” *American Economic Review*, 102(1):504-23.