Effects of educational attainment on climate risk vulnerability

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Abstract— **In the context of still uncertain specific effects of climate change in specific locations we stress that education should be seen as a central factor that both increases coping capacity with regard to particular climatic changes and improves the resilience of people to climate risks in general. Our hypothesis is that investments in universal primary and secondary education around the world are the most effective strategy for preparing to cope with the still uncertain dangers associated with future climate. The empirical evidence presented for cross-country time series of factors associated with past natural disaster fatalities since 1980 in 108 countries confirms this overriding importance of education in reducing impacts. We also present new projections of populations by age, sex and level of educational attainment to 2050 which provide an appropriate tool for anticipating societies' future adaptive capacities based on alternative education scenarios associated with different policies.**

INTRODUCTION

There is little doubt that climate change is already ongoing and more change is to be expected (Solomon et al. 2007). A number of organizations have assessed the costs of adapting to these changes, with the most recent of these estimates being in the range of $70 - 100 billion each year, and with the greatest losses associated with an increase in magnitude and frequency of extreme weather events (World Bank 2010b). However, the specific effects of climate change that will be experienced in specific locations are highly uncertain, and this creates a challenge for investments into climate-protective infrastructure (Dessai et al. 2009). An increasing number of researchers, both in academia (Agrawal and Perrin 2009, McBean and Rodgers 2010) and in the public sector (Agrawala et al. 2008, Schipper et al. 2008, World Bank 2010a), suggest that the most sensible investments in adaptation, or government interventions, may be those that focus not on directly addressing particular climatic changes, but which rather improve the resilience and reduce the vulnerability of people to climate risks in general. Here we examine the effects of one particular intervention, education, on losses from extreme weather events.

The idea that social and human development can improve resilience to climate change and extreme weather events is not new. A number of studies have compared losses from climate hazards with a number of development indicators, finding significant correlations with income, population density, access to drinking water, female fertility, and a number of indicators of good governance and public corruption (Yohe and Tol 2002, UNDP 2004, Brooks et al. 2005, Kellenberg and Mobarak 2008, Patt et al. 2010). The more recent of these (Kellenberg and Mobarak 2008, Patt et al. 2010) have looked explicitly at the human development index (HDI) as an indicator of disaster vulnerability. HDI is a composite indicator derived from indexes of income, life expectancy at birth, and education. These studies have revealed a non-monotonic relationship, that as yet is causally unexplained: initial improvements in HDI correlate with increasing vulnerability to climatic risks, while further improvements then correlate with falling risk levels.

No detailed empirical study to date has broken down HDI into its composite elements to consider education alone, nor has any study compared the effects of different education indicators. A possible reason for this could have been the lack of detailed and consistent empirical information on level of education across countries and over time. This situation has recently been improved through the reconstructions and projections of educational attainment distributions by age, sex and four levels of educational attainment for more than 120 countries in the world (Lutz et al. 2007, KC et al. 2010). A critical feature of these data, which has allowed researchers to use them to show the effects of education on economic growth, was their disaggregation of education across age groups.

There are several reasons to expect empowerment through basic literacy and subsequently secondary education to reduce vulnerability to climate change related risks. Most directly, better education typically implies better access to relevant information, such as early warnings for tropical storms or seasonal prediction of drought (Patt et al. 2007, Moser and Ekstrom 2010). Second, there is evidence that education also enhances cognitive skills and the willingness to change risky behavior while at the same time extending the personal planning horizon (Neisser et al. 1996, Behrman and Stacey 1997, Nisbett 2009). Third, there is scientific evidence that education leads to better health and physical wellbeing at any given age, in virtually every country (Fuchs et al. 2010, KC 2010). Fourth, more education leads to higher income at the individual and household level as well as higher economic growth at the aggregate level (Becker 1993, Schultz 1993, Lutz et al. 2008). All of these effects ought to play a role in reducing vulnerability to climate hazards.

MATERIALS AND METHOD

To investigate the link between disaster risk, development in general, and education in particular, we used data from the Emergency Events Data Base (EM-DAT) provided by the Centre for the Research of the Epidemiology of Disasters (CRED 2004) which provides information on the number of disasters, as well as the number of deaths caused by these disasters by country and year since 1980. Although data is available for a broad range of different types of disasters, we concentrate on floods, droughts, and storms because they most closely resemble the kinds of disasters to be expected to increase due to climate change.

Whether a specific event gets counted as a disaster in EM-DAT is determined by fulfillment of one of the following criteria: (1) Ten or more people reported killed, (2) one hundred or more people reported affected, (3) a call for international assistance was issued (4) a state of emergency was declared. Due to these specific criteria there is of course the possibility of sample selection bias. Some countries may have experienced a natural disaster, but because they were so well prepared none of the criteria necessary to be counted as a natural disaster were fulfilled. On the other extreme, in some very poorly developed regions disasters may have killed many people but due to poor information it may not even be registered and hence would not enter this data base. In both cases, however, the estimated effects of development indicators on disaster deaths would only be biased downward. For a comparison of EM-DAT with other sources of disaster data, as well as a discussion of the strengths and weaknesses of these data see (Guha-Sapir and Below 2002).

Data on the level of human development and its components was taken from the United Nation's Human Development Report (UNDP 2010). The HDI is a composite index measuring progress in the three basic dimensions – health, knowledge and income. While the methodology of the HDI has been changed slightly in its 20th anniversary edition, for reasons of compatibility and comparability with previous studies we used the original HDI where the knowledge-component was calculated using a combination of school enrollment and rates of adult literacy. Each of these is problematic: The problem with using school enrolment rates as an indicator of the population's human resource base is that it is a measure of current input (flow, investment in education) rather than of the skills of the adult population (stock). The problem with average adult literacy is the opposite, namely that it also includes old people and hence does not fully reflect major advances in human capital of the younger adults that resulted from recent expansions in schooling.

In order to circumvent these shortcomings, in addition to HDI and its components we also used data on the share of 20-39 year old women with completed secondary education or higher among the total female population aged 20-39 to control for education. Researchers have shown this to be the best predictor of different aspects of development (Lutz et al. 2008, Lutz et al. 2010). The data on educational attainment by age and sex was taken from the IIASA/VID data set (Lutz et al. 2007) which offers full education details by age and sex for 123 countries from 1970 onwards in 5-year intervals.

For the regression analysis we aggregated the data into 5- and 10-year periods in order to limit the influence of extreme outlier-years when certain countries experienced particularly severe disasters with exceptionally high death counts and because some of the social variables were only available for 5-year intervals. We then estimated a number of multivariate models for the given panel of national time series. In all models we use the natural logarithm of the total number of deaths per thousand of population by country and period as our dependent variable. This probability of dying from disaster is then explained by different sets of development indicators – including education – after controlling for some general controls: Real GDP per capita is taken from the Penn World Tables (Heston et al. 2009), data on the degree of democracy are taken from the Polity IV database (Marshall and Jaggers 2002), data on population size, population density, as well as on infant mortality (IMR) stem from the 2008 revision of the World Population Prospects (United Nations and Social Affairs 2009).

$$deaths_{i,t} = \beta_0 + \beta_1 * hdi_{i,t} + General \quad (1)$$

$$deaths_{i,t} = \beta_0 + \beta_2 * hdi_{i,t}^{GDP} + \beta_3 * hdi_{i,t}^{EDU} + \beta_4 * hdi_{i,t}^{LEX} + General \quad (2)$$

$$deaths_{i,t} = \beta_0 + \beta_5 * pcgdp_{i,t} + \beta_6 * eduF_{i,t} + \beta_7 * imr_{i,t} + General \quad (3)$$

$$General = \beta_8 * polity2_{i,t} + \beta_9 * nodis_{i,t} + \beta_{10} * density_{i,t} + \beta_{11} * coastal_i + \beta_{12-30} * region_i$$

Model (1) recurs to earlier findings by (Kellenberg and Mobarak 2008, Patt et al. 2010) who had used the HDI as an indicator of disaster vulnerability. HDI is a very comprehensive indicator of development outcomes, which in itself neither identifies the primary causes of vulnerability nor suggests a particular policy priority. Hence, in Model (2) we decompose the HDI into its three constituent sub-indices, one based on purchasing power adjusted per capita income, another one combining school enrollment and literacy rates, and finally an index derived from average life expectancy at birth. Including these three individual components of HDI separately in Model (2) yields estimates for the relative importance of the three dimensions on the number of deaths from natural disasters. Yet, as discussed above, the education sub-index of the HDI might not be the best way of accounting for the human capital of those segments of the population that matter most for vulnerability to disaster. Model (3) therefore uses our alternative education variable ($eduF_{i,t}$) to account for human capital.

All three models also consider the effect of income. Whereas GDP is implicitly included in the HDI in Model (1), Model (2) controls for income explicitly by using the GDP-component of the HDI ($hdi_{i,t}^{GDP}$). Model (3) which intentionally refers to indicators other than those of the HDI uses the natural logarithm of real per capita gross domestic product ($pcgdp_{i,t}$). This can help us to address an important question for policy priority setting, namely whether income matters more than education in reducing a country's disaster death counts.

Furthermore, we assume that the quality of a country's health system should play a significant role in minimizing human losses from natural disasters. Models (1) and (2) include life expectancy at birth, implicitly in the HDI and as a separate index. But since disaster deaths in a given year are also reflected in the life table and hence life expectancy of that year, in Model (3) we use the log of the infant mortality rate ($imr_{i,t}$) as an alternative indicator of health system quality. While infant mortality is not necessary less affected by this possible endogeneity, it would be differently affected (unless the proportion of infant deaths of all deaths are exactly the same in disasters and under normal conditions), and hence can be viewed as sensitivity analysis.

In addition to these different development indicators all three models control for a set of other variables labeled "$General$" in the equations above. The exposure to climate related risk is accounted for in our models as the log of the total number of disasters in the given period normalized by the total population size in 1000s ($nodis_{i,t}$). We also control for population density ($density_{i,t}$), which has been found significant in explaining casualty numbers by (Yohe and Tol 2002) and more recently by (Patt et al. 2010). In terms of the political system of the country we include the Polity score ($polity2_{i,t}$)which has the highest values for modern free democracies. We also control for the geo-physical fact whether a country is land-locked or has a coastline ($coastal_i$), which may affect its expose to tropical storms and flooding. Finally, we control for possible regional particularities ($region_i$) in the form of regional fixed effects that could also account for other still uncontrolled factors in our models.

Due to the availability of population projections by age, sex and education (KC et al. 2010) we are also able to forecast adaptive capacity based on different education scenarios under the assumption of constant hazard levels.

RESULTS

Our analysis covers 137 countries over the time period 1980 – 2010. In the regression analysis we have complete data for 108 countries. Figure 1 depicts the bivariate relationship between the log of disaster deaths per 1000 on the vertical axis and the proportion of women with completed junior secondary or higher education in the age group 20-39. The hump shape observed in previous studies that have examined the relationship between disaster risk and aggregate HDI (Kellenberg and Mobarak 2008, Patt et al. 2010) is present when one examines the full sample of countries (left side), but then disappears when we exclude countries that experience very few climate disasters. For all countries which over the 30-years period experienced at least 30 disasters, i.e. one or more disasters on average per year, it shows a clearly negative and almost linear association.

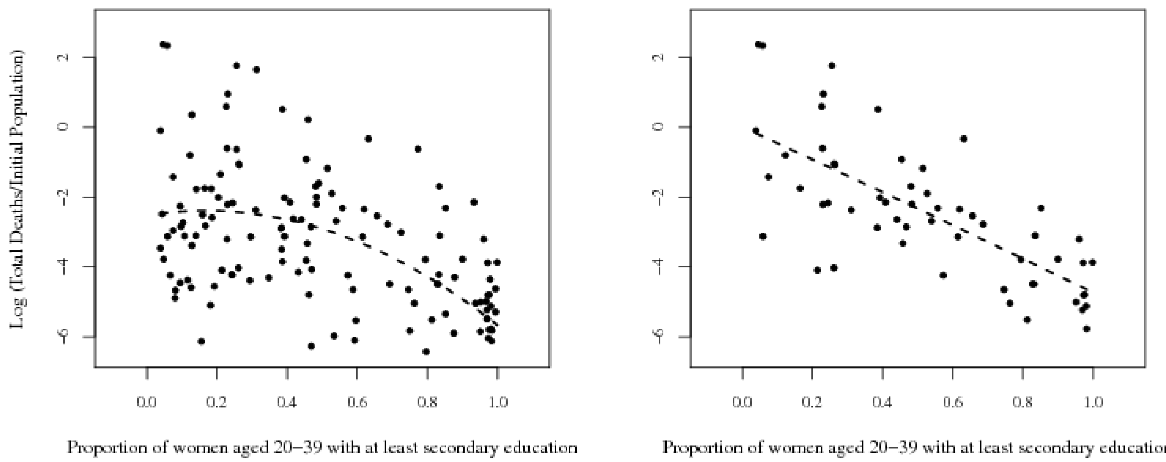

Fig. 1: Relationship between the log of disaster deaths (per 1000 of 1980 population) and female education (proportion with secondary and higher education among women aged 20-39) for all 137 countries (left side) and 56 countries with one or more disasters on average per year (right side).

For the given panel of national time series we specified various multivariate models in which the probability of dying from natural disasters is related to various indicators of risk as well as social and economic background factors. Results of three of them are displayed in Table 1, where two neighboring columns always belong to one model specification. As can be seen from the number of observations the left column of each model corresponds to 5-year intervals and the right column to 10- year intervals.

	Model (1)		Model (2)		Model (3)	
	5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
Log (Disasters/Pop in 1000)	0.697***	0.662***	0.699***	0.635***	0.724***	0.684***
	(0.071)	(0.106)	(0.070)	(0.105)	(0.070)	(0.105)
Log (Density)	0.182***	0.242**	0.185***	0.220**	0.181**	0.244**
	(0.070)	(0.099)	(0.071)	(0.099)	(0.072)	(0.102)
Polity Score	0.274*	0.373*	0.256*	0.333	0.314**	0.421*
	(0.144)	(0.215)	(0.143)	(0.211)	(0.145)	(0.216)
Coastal Country	1.113***	0.967***	1.102***	0.925***	0.861***	0.656***
	(0.183)	(0.259)	(0.181)	(0.254)	(0.177)	(0.251)
HDI	−5.840***	−6.874***				
	(0.850)	(1.206)				
EDU component of HDI			−3.492***	−5.270***		
			(0.732)	(1.042)		
GDP component of HDI			−0.564	−0.807		
			(0.805)	(1.143)		
LEX component of HDI			−2.816**	−1.678		
			(1.138)	(1.625)		
Log (IMR)					0.633***	0.797**
					(0.225)	(0.325)
Log (GDP per Capita)					0.042	0.148
					(0.158)	(0.228)
Female 20-39 Sec+ Edu					−1.968***	−2.397***
					(0.450)	(0.638)
F-statistic	17.15	10.829	16.859	11.004	16.759	10.605
N	617	309	617	309	617	309

Table 1: Determinants of National Death from Natural Disaster. Panel regression for 108 countries over 5- and 10-year intervals between 1980 and 2010 using time fixed effects. The dependent variable is the log of deaths per capita. Numbers in parentheses are standard errors based on the heteroskedasticity- and autocorrelation-resistant covariance matrix. Other independent variables not reported here are dummy variables for 17 world regions. Signif. codes: 0 '*' 0.01 '**' 0.05 '*' 0.01 ' ' 1.**

Model (1) shows the well known negative relationship between the HDI and human disaster losses. For both panels (the 5-year and 10-year intervals) it is highly significant. Yet, it does not tell us, which of the individual components of the HDI are responsible for this decrease. Model (2) reveals that the only truly significant component of the HDI is the education index, comprised of school enrollment and literacy rates. Neither the GDP nor the life expectancy component shows significant additional explanatory power. Model (3) uses different indicators of educational attainment, income and health, yet the results turn out to convey the same story. Female education is most significant in reducing vulnerability to natural disasters. In addition, high infant mortality also turns out to be highly significant in showing high vulnerability to natural disasters. Since in addition to the quality of public health systems mothers' education is typically considered a key determinant of infant mortality (Fuchs et al. 2010) these two significant parameters essentially show two sides of the same story: social development with a focus on the empowerment of women and the health of their children.

The parameters for the control variables mostly have the expected signs and their significance varies among the models. The frequency of disasters as the key variable measuring the exposure of countries to disasters independent of the number of fatalities is as expected consistently positive and highly significant under all models. Similarly, the fact that a country has a coast line turns out to have a consistently positive effect on the number of fatalities and is significant under most models. Also, not surprisingly a country with higher population density on average experienced a higher number of casualties. What is rather surprising at first sight, however, is the positive relationship between vulnerability and the democracy score. This seems to imply that in more authoritarian countries ceteris paribus the vulnerability to natural disasters is reduced. While this may in part be true for certain cases such as Cuba, Iran, Singapore and others that have very efficient disaster control systems while not being free democracies and on the other hand countries such as India and Bangladesh having serious problems in handling disasters while being labeled as democracies, there remains a selectivity issue. Democratic governments may be more ready to report disaster deaths than authoritarian ones. Clearly, this issue warrants further in depth research in the future.

In sum, the results presented in Table 1 clearly show that education (and in particular female education) is the single most important social and economic factor associated with a reduction in vulnerability to natural disasters. Both in the form of the education component of the HDI and as measured by the proportion of the female population aged 20-39 with junior secondary and higher education it has the most significant and consistently positive effects under all models and also when considering 5-year as well as 10-year intervals. In terms of setting policy priorities and in linking this to economic studies of vulnerability, which often uncritically start from the assumption that higher income is the key determinant for reducing vulnerability, it is important to note that in none of the models income (whether in the form of the income component of the HDI or as conventional GDP per capita or its growth rate) turns out to be significant if education is being considered at the same time.

Table 1 shows that consistently female education (using the indicator described above) turns out to be the most important socio-economic factor in reducing the death toll from natural disaster. In contrast, neither the level nor the growth rate of GDP p.c. turns out to have a significant effect. If instead of those variables the three components of the HDI are included in the model, again the education component comes out much stronger than the income and health components. This robust aggregate level finding now needs to be complemented by further micro-level evidence.

DISCUSSION

Once the key role of education in reducing vulnerability to natural disasters is firmly established, new projections of populations by age and level of education (KC et al. 2010) can also be used to anticipate the future adaptive capacities of societies. Figure 2 shows the population pyramid for Sub-Saharan Africa in 2050 with the colors indicating the level of education. Men and women without any formal education are marked in red, those with some primary in yellow, those with completed junior secondary in light blue and those with tertiary in dark blue Today more than half of young adult women in Africa are still without secondary education. For 2050 Figure 2a depicts the results of projections in which age-specific school enrolment rates at all levels are kept constant at their current levels which means that schools are only expanding in parallel with the growth of the school age population (CER, Constant Enrolment Rates Scenario). In contrast Figure 2b shows a scenario in which school enrolment rates over the coming years increase following the path of other countries that had been at the same level earlier (GET, Global Education Trends Scenario). In both cases the 2050 population sizes (1.9 billion in CER and 1.7 in GET) will be a lot bigger than today (0.8 billion) with the difference between CER and GET resulting from the fact that more educated women have lower birth rates. Under the CER Scenario the number of young adults (and in particular women) will increase dramatically while under the GET Scenario most of the added population will be men and women with secondary or higher education (in blue).

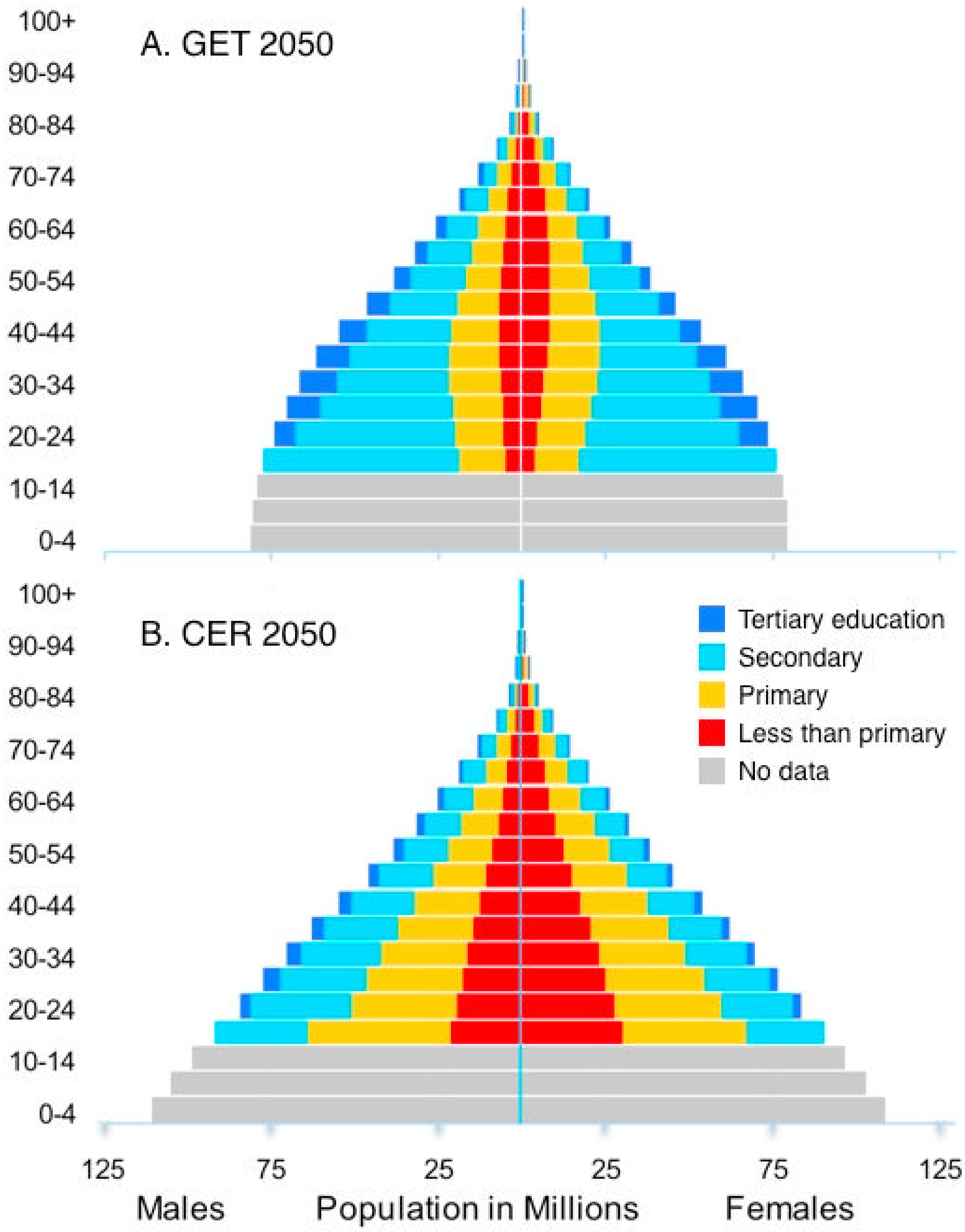

Fig. 2: Age pyramids by level of education for Sub-Saharan Africa: (a) for 2050 under the constant enrollment rates scenario and (b) for 2050 under the global education trends scenario.

These are two very different societies projected for 2050. In light of the empirical analysis presented here, the first one would be highly vulnerable to possible increases in natural disasters due to climate change, while the second one would likely have considerably more adaptive capacity to cope with whatever changes the future will bring. While calculating the exact number of lives that can be saved by increasing investments into education is impossible because of the high uncertainty around future risk levels, we can use the upper and lower bounds of past disaster risk levels to calculate the number of deaths under the CER and the GET Scenario. A first back-of-the-envelope calculation combining the projections shown in Figure 2 with our regression results from Model (3) in Table 1 reveals that in the time-period 2040-2050 the number of deaths due to natural extreme events in Sub-Saharan Africa under the CER Scenario will be in the range of 10100 – 228000 while under the GET Scenario the predicted number of deaths ranges from 3700 to 83900. Regardless of the risk level the ratio between the scenarios is relatively stable and important. It can account for between 6400 and 144400 additional lives saved or lost, which corresponds to a reduction of roughly 60%. Note that this tremendous effect is not only due to the increased share of women aged 20-39 that have completed at least secondary education, which will have reached almost 70% under the GET Scenario, compared to just 30% under the more pessimistic outlook. The direct effect of education is combined with its indirect effect via reducing the affected population size as well as population density. If in the future there are more disasters than in the past the effect would be even stronger.

Which scenario will actually be more likely depends on education policies in the near future. If nothing happens and school expansion does not even keep pace with population growth the outcome would be even worse than under the CER Scenario. There are of course many other important reasons for expanding school enrolment (and at the same time also enhancing the quality of schooling) in terms of positive effects on health and poverty reduction which have lead to the inclusion of universal primary education as a Millennium Development Goal. But viewing education as an investment in the adaptive capacity to climate change would be an important new policy focus.

CONCLUSION

It is likely that over the next years, large amounts of money will be spent on adaptation programs through the Kyoto Protocol adaptation fund, national governments, or other donors. But there is not enough of a scientific basis to guide these funds into directions that are meaningful under a long-term perspective. There is serious concern that significant funds might be channeled into "investments" that (given the strong path dependence of, e.g., agricultural policies) lock countries into certain paths that are not tenable under future climates. Alternatively, given the uncertainty about the precise manifestations of climate change in specific areas, it may be better to increase the general flexibility and enhance the human and social capital through massive new investments in universal basic education in order to empower the populations to better cope with climate change in a way that will be to their best long-term benefit.

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