The Economics of Population Policy for Carbon Emissions Reduction in Developing Countries

David Wheeler and Dan Hammer

Abstract

Female education and family planning are both critical for sustainable development, and they obviously merit expanded support without any appeal to global climate considerations. However, even relatively optimistic projections suggest that family planning and female education will suffer from financing deficits that will leave millions of women unserved in the coming decades. Since both activities affect fertility, population growth, and carbon emissions, they may also provide sufficient climate-related benefits to warrant additional financing from resources devoted to carbon emissions abatement. This paper considers the economic case for such support. Using recent data on emissions, program effectiveness and program costs, we estimate the cost of carbon emissions abatement via family planning and female education. We compare our estimates with the costs of numerous technical abatement options that have been estimated by Nauclér and Enkvist in a major study for McKinsey and Company (2009). We find that the population policy options are much less costly than almost all of the options Nauclér and Enkvist provide for low-carbon energy development, including solar, wind, and nuclear power, second-generation biofuels, and carbon capture and storage. They are also cost-competitive with forest conservation and other improvements in forestry and agricultural practices. We conclude that female education and family planning should be viewed as viable potential candidates for financial support from global climate funds. The case for female education is also strengthened by its documented contribution to resilience in the face of the climate change that has already become inevitable.

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1. Introduction

Extensive empirical research has shown that social and economic development are promoted by investments in family planning and female education (King and Mason, 2001). Multilateral and bilateral donors finance these investments on their own merits, and no further rationale is needed. However, donor resources remain scarce, and few would argue that the current level of support for family planning and female education is adequate. Female education provides a compelling case in point: The world's poorest regions are far from universal primary education for females, and secondary participation rates are often abysmal.

Table 1 presents data on the prospects for female education in Sub-Saharan Africa from 2000 to 2050, with projections from the methodology that we develop and explain in this paper. The projections are based on internally-consistent assumptions about the paths of carbon emissions, economies, populations and human development indicators.[1] In 2010, the number of school-age females in school is approximately equal to the number who are not. The educational shortfall is larger for secondary school, which has higher per-pupil expenditures than primary school. Using the best available data on expenditures per pupil, we estimate that about $9 billion would be required in 2010 to increase primary and secondary enrollment rates to 100%.

In Table 1, the net female primary school enrollment rate increases from 57% in 2000 to 93% in 2050, and net secondary enrollment from 22% to 79%. The projected improvements are striking, but they occur while school-age populations are increasing and expenditures per pupil are rising with incomes. In 2050, the educational deficit has actually increased to $10.8 billion (in constant dollars). In Section 6, we present similar projections for all developing countries, for both female education and family planning. They suggest that the relevant Millennium Development Goals will not be reached for decades unless additional financial support can be mobilized.

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[1] We draw on forecasts developed by one of the authors and his co-authors in Blankespoor (2009). We incorporate economic growth projections from a recent summary of integrated assessment models by Hughes (2009), who draws on a critical assessment of the IPCC's emissions scenarios by Tol, et al. (2005). Hughes develops a consensus economic projection by taking average growth rates from five integrated assessment models. Our demographic forecasts (which include projections of life expectancies, total fertility rates and female age cohorts) are drawn from the UN's Medium Variant Projection (2006 Revision). Projections for net female educational enrollment rates, numbers of students, and costs reflect econometric estimates reported in Sections 4 and 5 of this paper.

While budgets for these activities remain insufficient, concern about global warming has prompted rapidly-growing support for carbon emissions abatement and adaptation to climate change in developing countries. The global dialogue includes many proposals for using huge sums to finance a rapid transition to low-carbon growth. However, little attention has been paid to the possibility that financing expanded female education and family planning could make a significant contribution to carbon abatement. Our paper attempts to contribute by assessing their cost-effectiveness in this context.

The remainder of the paper is organized as follows. In Section 2 we review recent evidence on the critical implications of climate change for developing countries, with particular attention to the rapid growth of their carbon emissions. Section 3 discusses the economics of emissions abatement, focusing on recent cost estimates for abatement options related to energy efficiency, low-carbon energy and changes in forestry and agriculture. In Section 4, we broaden the option set to include female education and family planning. We estimate country-level CO2 emissions per person; calculate emissions reductions from reduced fertility; estimate the impact of female education and family planning programs on fertility; and calculate the costs of those programs. We combine our calculations to produce country-level estimates of CO2 abatement costs via female education and family planning. Section 5 presents our results and compares them to cost estimates for other abatement options. Section 6 discusses the implications for the climate change agenda, while Section 7 summarizes and concludes the paper.

2. Climate Change and Developing Countries

2.1 The Climate Challenge in Developing Countries

In an analysis of future greenhouse emissions, Wheeler and Ummel (2007) find that the developing-country share of cumulative atmospheric carbon loading is likely to reach 50% by 2030 (Figure 1). Before the current recession, developing-country emissions were rising faster than the worst-case projection of the Intergovernmental Panel on Climate Change IPCC, 2007) (Figure 2). The clear implication is that unchecked carbon emissions from developing countries pose a major threat – to themselves as well as developed countries. As atmospheric greenhouse gases accumulate, it will get steadily warmer, the sea level will continue rising, and the weather will be more variable, with more intense rainfall in some places and more intense droughts in others (IPCC, 2007). Coastal storms are likely to intensify, since the ocean will be warmer (Emmanuel, 2005; Webster, 2006) Storm surges will be magnified by sea-level rise, pushing further inland and creating more potential for damage. Recent research indicates that some areas will be hit much harder than others. For example, a one-foot rise in sea level, which will probably occur within thirty years, will begin submerging a large area of the Nile Delta, Egypt's breadbasket (Dasgupta, et al., 2009b). Millions of people in low-lying areas of

Manila and other coastal cities will be in critical danger from typhoon-driven storm surges (Dasgupta, et al., 2009a). Agriculture is also likely to be hard-hit in many areas, with India and Sub-Saharan Africa facing productivity losses of 40% or greater by 2080 (Cline, 2007) (Figure 3). All of these effects will strike developing countries more severely than developed countries, for two reasons: Developing countries are in higher-risk areas, and they are more vulnerable because they have fewer economic, human and institutional resources.

In summary, developing countries will be the dominant source of global warming within a generation, as well as the primary victims of climate change. It therefore seems realistic to assert that the global climate struggle will be won or lost in the developing world. But poor countries can ill afford the extra cost of low-carbon technologies, so India, China, South Africa and other rapidly-industrializing countries are expanding their use of fossil fuels (particularly coal) despite plentiful renewable power resources (Buys, et al., 2009). In a similar vein, the drive for economic growth and poverty reduction propels carbon emissions from deforestation in Indonesia, Brazil, the Democratic Republic of the Congo and other rainforest countries.

2.2 Policy Responses

Although this threat is widely acknowledged, there has been no commensurate policy response. Without a credible U.S. commitment to significant carbon emissions reduction, China, India and other major developing-country emitters will remain uninterested in limitations. And developing countries continue to insist that they will only commit to significant emissions limitations if developed countries agree to finance the incremental costs of clean energy, forest conservation, and other carbon-saving options.

The power sector currently accounts for over 25% of global carbon emissions, and continued growth in poor countries will require trillions of dollars in new energy investments. Since donor resources will never exceed a small fraction of this sum, they can only make a significant contribution if they focus on driving the cost of renewable energy below the cost of power from combustion of fossil fuels (particularly coal). This imperative dictates strategic investments that exploit scale and learning economies to reduce the cost of energy from renewable technologies that are scalable and commercially available (Ummel and Wheeler, 2008; Neij, 2009). Donor countries have acknowledged this imperative by pledging several billion dollars to the Clean Technology Fund, administered by the World Bank (Paulson, et al., 2008; World Bank, 2008a). This is likely to be the opening wedge for many billions in financing that will ultimately be required (Stern, 2006).

Forest clearing is also an enormous contributor to global warming, accounting for some 20% of annual greenhouse gas emissions (WRI, 2009). Most forest clearing occurs in developing countries that have limited resources and regulatory capacity. Since these countries understandably focus their energy and resources on poverty alleviation, their support for forest conservation will be weak as long as forested land has a higher market value in other uses. Under these conditions, many proprietors will continue clearing their forested land unless they are given conservation payments that match or exceed the opportunity cost of the land. This economic insight has led the UN to establish UN-REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), a program that helps countries prepare for an eventual direct compensation scheme for forest conservation. The first prototype for REDD operations is the World Bank's Forest Carbon Partnership Facility (FCPF), launched at the UN's Bali conference on climate change in December, 2007. Target capitalization for this prototype facility is over $300 million (World Bank, 2008b). However, the UNFCCC estimates that full conservation of remaining forests in the tropics and subtropics will require $12.2 billion annually (UNFCCC, 2007). An international compact may eventually support an expansion of UN-REDD to this scale, because carbon emissions abatement from forest conservation is much lower-cost than abating emissions from fossil fuels (Stern, 2006).

To summarize, developing countries hold the key to a safe and sustainable climate agreement, but their cooperation will depend on developed countries' willingness to finance the transition to a low-carbon economy. Mobilizing the required resources will not be easy, and it will be critical to identify emissions abatement options that are both cost-effective and deployable at large scale.

3. Carbon Emissions Mitigation and Costs

To facilitate the adoption of such approaches, Sokolow and Pacala (2004) have identified options, which they term "wedges", that have the potential to reduce carbon emissions by 1 gigaton (GtC) (or 3.67 Gt of CO2) annually by 2054. Full exploitation of each wedge would reduce total emissions by 25 GtC (or 91.8 GtCO2) over 50 years, accounting for 1/7 of the reduction needed to stabilize carbon emissions. Sokolow and Pacala identify 15 options whose potential contribution is at least one wedge, and in some cases more.

Extending the Sokolow/Pacala initiative, Nauclér and Enkvist of McKinsey and Company (2009) have developed cost estimates for a large set of options that have an aggregate potential to abate 38 Gt of CO2 per year by 2030. The options can be classed into three broad groups: energy efficiency (with an opportunity for 14 Gt of CO2 abated by 2030), low-carbon energy (12 Gt CO2), and reduction of terrestrial carbon emissions from deforestation and agriculture (12 GtCO2). Table 2 presents the Nauclér/Enkvist options in ascending order of cost (in $US per ton of CO2 abated).[2] Options are grouped

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[2] The costs in Figure 2 are converted from Euros in Nauclér and Enkvist to dollars at the prevailing exchange rate on August 1, 2009.

in sets that contribute about 5 Gt of CO2 abatement, and are assigned to one of the three broad groups identified above. Although there is considerable overlap, each group is clustered in a particular cost range. The energy efficiency measures are all in the "win-win" category, heavily clustered in the negative cost range from -\$10/ton CO2 to -\$130/ton. The options in forestry and agriculture are generally clustered in the low positive cost range, with an upper limit around \$20/ton. The low-carbon energy options are the most dispersed, with significant representation in the low positive cost range and heavy clustering in the high range, from \$25/ton to \$90/ton. Across cost ranges, "win-win" options account for about 15 Gt of potential CO2 mitigation, low positive cost options for about 10 Gt, and high positive cost options for the remaining 13 Gt.

The entries in Table 2 reflect the Sokolow/Pacala engineering approach, which focuses on specific technical options for large-scale CO2 reduction. A different approach has been taken by economists such as Nordhaus (2007), whose models endogenize technical choice and focus on market-based regulatory systems that mitigate carbon by taxing carbon emissions.[3] Bongaarts (1992), Birdsall (1992), O'Neill et al. (2001) and others have taken a third approach to mitigation, highlighting the role of population growth as a determinant of increasing carbon emissions. Recent research by O'Neill et al. (2010) suggests that slower population growth from feasible reductions in fertility could yield the equivalent of at least one Sokolow/Pacala wedge (3.7 Gt of CO2 abatement annually) by 2050, and significantly more in later years.

If O'Neill and his colleagues are correct, then programs that promote fertility reduction seem appropriate for cost-comparison with the alternatives proposed by Nauclér/Enkvist and Sokolow/Pacala. Two important options in this context are investments in family planning and female education, which empirical research has identified as powerful determinants of fertility (Wheeler, 1984; Cochrane, 1988; Sanderson, 1998; Gatti, 1999; Birdsall et al., 2001). As we noted in the introduction, current human development budgets are not likely to close funding gaps in the billions of dollars during the coming decades. An intriguing "win-win" possibility therefore emerges: If fertility reduction via family planning and female education offers a cost-competitive "wedge" for emissions abatement, then these programs may qualify for some of the billions in subsidies that will otherwise be focused exclusively on technical options like those identified by Sokolow/Pacala and Nauclér/Enkvist.

The question of cost-competiveness can be resolved empirically by calculating costs per ton of CO2 abated for the two population policy options. For each option, the calculation divides the policy's cost per birth averted by the emissions prevented. In pioneering work on this issue, Birdsall (1992) drew on limited evidence to estimate costs between \$3.20 and \$6.40 per ton of CO2 abated for family planning, and between \$2.10

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[3] Market-based regulatory systems include both carbon taxation and cap-and-trade, since carbon is priced in the market for emissions permits in the latter.

and \$4.30 per ton for female education.[4] Corroboration of these estimates with more recent data would establish both policies as more cost-effective than almost all the entries in Table 2 for low-carbon energy, forestry and agriculture.

4. Population Policies and Abatement Costs

With more plentiful recent data, we compute abatement costs for family planning and female education at the country level. For comparison with the global estimates in Table 2, we also compute global weighted costs, where countries' weights are determined by their relative potentials for fertility reduction. Our approach is conservative: We include several robustness checks, and maintain the practice of choosing the higher of two costs when our methodology requires a choice.

We calculate the average CO2 emissions intensity (emissions/population) for each country, using the latest available data on emissions from fossil fuel combustion and deforestation. We include estimates from two approaches to emissions accounting for deforestation, since this remains contentious in the scientific literature. Our baseline calculation assumes that annual abatement from a birth averted (or marginal intensity) is equal to the average emissions intensity. To check for robustness, we do an alternative computation in which the marginal intensity is reduced to 25% of the average intensity.

For family planning activities, we use a country-level database of estimated annual program costs per birth averted. Some uncertainty attaches to these estimates, so we do a robustness check by multiplying them by 10 in an alternative computation.[5] Much less uncertainty attaches to the cost of female education, since the World Bank's World Development Indicators include country-level expenditures per pupil at the primary and secondary levels. Where our methodology forces us to choose, we use secondary expenditure for two reasons. First, the most recent evidence (Section 4.3; Table 3) suggests that secondary enrollment is a more powerful determinant of fertility change than primary enrollment. Second, following our conservative posture, we choose secondary expenditure per pupil because it is almost always higher than primary expenditure.[6]

We calculate unit costs in \$US 2009 for direct comparison with the Nauclér/Enkvist estimates in Table 2. We also employ their accounting methodology by converting all

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[4] The actual figures in Birdsall (1992) are \$6 - \$12 per ton of carbon for family planning, and \$4 - \$8 per ton for female education. We have converted these to current dollars using the US GDP deflator, and from carbon to carbon dioxide using the standard conversion factor (44/12).

[5] Our tenfold multiple incorporates the critique of Pritchett (1994), whose empirical work suggests that conventional estimates of fertility reduction via family planning are too high. For micro-evidence on costs per birth abated in Bangladesh, see Attanayake, et al. (1993), Balk, et al. (1988), and Simmons, et al. (1991).

[6] The latter is higher in some Latin American countries, according to the World Bank's World Development Indicators.

elements of the calculation into annualized flows.[7] Emissions intensity is already annualized. Focusing on the youngest fertile-age female cohort, aged 15-24, we treat female education and family planning activity as investments that are amortized over each woman's child-bearing years. We assume a thirty-year period, and follow Nauclér and Enkvist by amortizing at a 4% discount rate.

4.1 Emissions Intensities

From an online database maintained by the World Resources Institute (WRI, 2009), we obtain estimates of annual CO2 emissions from combustion of solid, liquid and gaseous fuels, cement manufacturing, and gas flaring. These data cover 185 developed and developing countries. For CO2 emissions from land-use change, we employ the latest estimates from two sources that use different methods for calculating carbon fluxes: Houghton, et al. (2007) and de Campos, et al. (2005, 2007). Despite collaboration by Houghton and de Campos themselves, as reported in Ito, et al. (2008), no consensus approach has yet emerged. Since neither method is clearly preferred, we develop three estimates for emissions from deforestation in each country: the mean of Houghton and de Campos, the minimum of the two, and the maximum. We add them to the WRI emissions estimates and divide by population to obtain three intensities, adopting the mean-based calculation as our baseline intensity. As we noted previously, we also introduce a scenario in which the marginal emissions intensity is 25% of the baseline intensity.

4.2 Unit Costs for Family Planning

For family planning programs, we estimate the cost per birth averted from a database that summarizes evidence from a survey exercise for 56 countries sponsored by the Alan Guttmacher Institute (AGI, 2000; Matheny, 2004). We use these data directly for one set of estimates. We also do an alternative computation, using an econometric approach that enables us to extend the dataset significantly. In this approach, we estimate a model of cost per birth averted and use it to predict costs for countries that do not have direct observations. One of the highly-significant independent variables in our model is female secondary education which, despite improvements in data availability, is still far from universally recorded. From the World Bank's World Development Indicators, we have assembled a panel database of net female secondary enrollment rates.

Starting with the education data, we develop augmented estimates of costs per birth averted in two steps. First, we estimate a predictive equation for the net female secondary enrollment rate. Using predicted values from this equation where direct observations are not available, we produce a secondary enrollment dataset for 106

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[7] For a detailed discussion, see Nauclér/Enkvist, pp. 147-149.

developing countries. Then we estimate a model of costs per birth averted that incorporates the size of the fertile-age female population and the female secondary education rate. The results confirm our prior expectations: significant scale economies (lower costs for larger fertile-age cohorts), and higher family planning productivity in more educated populations (lower costs per birth averted for higher secondary enrollment rates). After estimating the equation, we predict unit costs for developing countries that do not have directly-observed values. This expands the dataset on unit costs from 60 to 106 developing countries. In Section 5, we report results for both the directly-observed and econometrically-augmented datasets.

4.3 Female Educational Enrollment Rates

Table 3 reports results for two sets of regressions, which are estimated using directly-observed data. In column (1), we report fixed-effects results for a conventionally-specified equation that relates the total fertility rate to primary and secondary schooling, life expectancy and income per capita. This result is of independent interest, for two reasons. First, it estimates by fixed effects, which has not been possible until recently because female enrollment data have been too sparse. This permits a much stronger test of hypothesized relationships than previous cross-sectional work. Second, our results employ the most recently-available data, and they are quite powerful: All regression variables have the expected signs and very high levels of significance. The most interesting result is the dominance of female secondary education, whose estimated impact on fertility is three times the impact of primary education. The overall quality of the fit is extremely high, with a regression R^2 of .99 for 978 observations.

For purposes of prediction, we re-specify equation (1) as an association between female schooling and three variables: life expectancy, income per capita and the total fertility rate. We estimate equations (2) and (3) for primary and secondary enrollment, respectively.[8] Not surprisingly, the results are also very robust. The estimated parameters for life expectancy and the total fertility rate have the expected signs and are highly significant in both equations. Income per capita is insignificant in the primary schooling equation, but highly significant in the secondary schooling equation. Overall, the fits are excellent: R^2 is .87 for the primary schooling equation with 932 observations, and .98 for the secondary schooling equation with 727 observations.

We use the results from equation (2) to predict values for female secondary enrollment rates for countries where direct observations are not available. This expands coverage from 66 to 106 developing countries, and the quality of the regression fits suggests that our predictions should be reasonably accurate.

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[8] We specify the education rates as logits, to ensure that predictions are restricted to the interval 0-100%. For a probability p between 0 and 1, the logit is defined as log [p/(1-p)]. This is an appropriate specification for the regressions in any case, since it is consistent with natural lower and upper bounds for net enrollment rates.

4.4 Unit Costs for Averted Births

We are limited to cross-sectional regression for analyzing the cost of an averted birth (or unit cost) via family planning, because we only have observations from AGI (2000) for one year. As we noted in Section 4.2, our regression model relates unit cost to fertile-age female cohort size and female secondary schooling. Table 4 reports estimation results: Both parameters have the expected signs and are significant at 99%; the regression R^2 is .32 for a sample of 67 developing and developed countries. We have also incorporated dummy variables for World Bank regions to improve prediction accuracy. Several dummies are highly significant, and provide useful regional baselines for countries that do not have directly-observed data. Using the regression results, we expand our unit cost database for developing countries from 60 to 106 countries.

From a human development perspective, family planning programs provide women with useful information about reproductive options and actions that can improve maternal and child health. From the much narrower perspective of this exercise, family planning is an investment that yields a reduction in fertility. For each country, our data provide an estimate of investment cost per averted birth. Since this is an investment, we calculate annualized family planning cost as an amortization of the investment over a 30-year childbearing period for the women in our focal cohort (15-24 years old). For direct comparison with Nauclér and Enkvist, we employ their discount rate (4%). At this discount rate over 30 years, the annualized payment is 5.78% of the original investment. We therefore calculate the annualized cost as the cost per birth averted, multiplied by .0578.

4.5 Female Primary and Secondary Expenditures Per Pupil

To compute projected schooling costs, we draw on the World Bank's World Development Indicators (WDI) to estimate panel regressions for primary and secondary expenditures per student as a proportion of gdp per capita.[9] After extensive experimentation with plausible explanatory variables (e.g., per capita income, size of student population), we find significance only for country, sub-regional and regional fixed effects. We use all three sets of fixed effects to get the most accurate estimates for countries that have no per-pupil expenditure data in the WDI. Then we multiply the estimates by per capita incomes to obtain predicted expenditures per primary and secondary student. From the WDI database, we have drawn observations on primary and secondary school expenditure for 71 countries. The set expands to 155 countries after our fixed-effects prediction exercise.

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[9] Delamonica, et al. (2001) have produced alternative schooling cost estimates for a broad cross-section of countries, but we have chosen the WDI panel data because they are sufficiently plentiful to support fixed-effects estimation.

As previously noted, we focus on secondary expenditure per pupil for two reasons: First, panel estimation results for the most recent data indicate that secondary education has a much stronger impact on fertility than primary education (Table 3). Second, use of secondary expenditure is more conservative than primary expenditure because the former is typically higher. To translate secondary expenditure per pupil into cost per birth averted, we draw on a strong regularity in the empirical literature cited by Gatti (1999) and King and Mason (2001): Three years of schooling are associated with a one-unit decline in the total fertility rate.[10] Schooling is also an investment, so we calculate annualized schooling cost as an amortization of the investment over a 30-year childbearing period for the women in our focal cohort (15-24 years old). Again, for direct comparison with Nauclér and Enkvist, we employ their discount rate (4%). At this discount rate over 30 years, the annualized payment is 5.78% of the original investment. So the full calculation of annualized cost per birth averted for education in a country is its secondary expenditure per pupil, multiplied by 3 (3 years of schooling translates to a one-unit decline in the total fertility rate for the youngest female cohort), and then by .0578 (to annualize the cost over 30 years at 4%).

5. Abatement Costs for Population Policies

5.1 Global Results

Using the methods described in Section 4, we calculate carbon emissions abatement costs that can be directly compared with the Nauclér/Enkvist estimates in Table 2. We create several scenarios for each country, with costs for family planning alone, female education alone, and the lower of the two costs. We compute "net fertility" for each country as the difference between its current total fertility rate and 2.0 (the replacement fertility rate).[11] We multiply net fertility by the number of young women in the age cohort 15-24, to produce an estimated potential number of births averted in that cohort. We compute total potential births averted for all countries in the sample, and divide countries' potential births averted by the global total to obtain country shares. Then we compute the global weighted unit cost of abatement by adding the share-weighted costs

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[10] Although they are not directly comparable, the results in Table 3 also shed light on this relationship. The estimated parameter for the net female secondary enrollment ratio (-.03) is extremely robust, since it is almost 20 times its standard error. For an individual female, the secondary enrollment rate can be interpreted as the probability of secondary schooling. The measurement range of the rate in equation (1) is 0-100%. Movement from no schooling to secondary school completion is the equivalent of moving the secondary enrollment rate from 0 to 100. An additional 12 years of education generates a reduction of 3 in the total fertility rate (100 x .03), or .25 per year of schooling. Our estimate therefore suggests a decline of .75 per three years of schooling – surprisingly close to Gotti's survey finding. It is also effectively identical to the finding of Klasen (1999). King and Mason (2001) argue that Klasen's result is somewhat lower than others because it does not fully incorporate long-term effects.

[11] For this exercise, we are assuming that replacement fertility represents the lower limit on average fertility within the relevant time frame.

for individual countries. We follow this same procedure for costs computed from directly-observed data, and for costs computed from econometrically-augmented datasets.

Table 5 presents our results for the direct case and three augmented cases: the baseline (the lower of family planning and education costs), family planning separately, and female education separately. We present five scenarios, which incorporate different handling of the Houghton/de Campos deforestation emissions estimates (average, maximum and minimum emissions); one case in which all country estimates for family planning costs are multiplied by 10; and one in which emissions intensities are reduced to 25% of the baseline figures. Multiplying all family planning costs by ten has the effect of increasing estimated carbon abatement costs for family planning tenfold, ceteris paribus. This effect is attenuated in the baseline case, which uses the lower of the two program costs in each country. Similarly, reducing all emissions intensities to 25% of the baseline has the effect of quadrupling all estimated carbon abatement costs, ceteris paribus. Again, the effect is reduced in the baseline case by the choice of the lower program cost in each country.

We have no reason to suppose that computations based on directly-observed or econometrically-augmented data have any particular bias. In the baseline case, the global average cost is automatically lower for the augmented dataset because it introduces more cost-minimizing options at the country level. Directly-observed costs do not change in the augmented dataset, but it does introduce many new cost estimates. Since the baseline method chooses the lower of the two program costs for each country, the overall effect of econometric augmentation is to lower computed global average costs.

In our five scenarios for the directly-observed and baseline (augmented) cases, results for the first three are quite similar because, at the global level, differences between the Houghton and de Campos estimates roughly balance. These cases all incorporate our baseline numbers for the cost of a birth averted via family planning and female education. In all three, the cost of carbon emissions abatement via population policy is about $4/ton of CO2 in the directly-observed case and slightly lower in the augmented cases. In comparison with the options in Table 2, these are highly competitive costs. They are at the low end of the forestry and agriculture options, and the extreme low end of the low-carbon energy options. The latter finding is particularly striking, because the global discussion of abatement has focused heavily on low-carbon energy options. Recalling O'Neill, et al. (2010), population policy has the possibility of reducing global emissions by at least one Sokolow/Pacala "wedge" (3.6 Gt of CO2 annually) by 2050. And comparison with the numbers in Table 2 indicates that the population policy options are far lower-cost than second-generation biofuels, nuclear power, wind power, solar power, or carbon capture and storage.

The same comparative results hold for the baseline cases for family planning and female education taken separately. Costs are around $4.50/ton for family planning and $10.00/ton for female education. Family planning alone is competitive with carbon capture and storage (CCS) options even after a tenfold cost multiplication, and this is obviously a very extreme assumption. After reduction of the marginal emissions intensity to 25% of the average intensity, family planning taken separately remains very cost-competitive (at $17.10) with nuclear, wind and solar power. When taken separately, female education is lower-cost than the CCS options at the 25% marginal emissions intensity.

5.2 Country-Level Results

While our global results provide a direct comparison with the Nauclér/Enkvist options, they are somewhat misleading because they ignore the implications of our results at the country level. Since programs are actually implemented in countries, these results are of considerable interest as well. Figure 4 provides the evidence for three augmented cases: The baseline (minimum cost option for each country), family planning alone and education alone. Countries are ranked in ascending order of cost for each variant. With Table 2 as the comparator, we set $5/ton as a competitive standard for forestry/agriculture options, and $20/ton as a standard for low-carbon energy options. We have calculated costs for our sample group of 88 developing countries. For the minimum cost and family planning-only options, 40 countries have costs below the $5 forestry/agriculture standard and over 70 have costs below the low-carbon energy standard. For female education, about 30 countries are below the $5 standard and 60 are below the $20 standard. To summarize, all three population policy option sets are cost-competitive with most of the Nauclér/Enkvist low-carbon energy and forestry/agriculture options in a large number of developing countries.

5.3 Family Planning vs. Female Education

In direct comparisons, abatement cost via family planning is lower than abatement cost via female education in 70% of the developing countries in our sample. However, our results strongly indicate that these two options are complementary rather than competitive. The econometric result for secondary education in Table 4 presents important evidence in this context: Family planning programs are more productive in societies with higher female education rates, so the cost per birth averted is lower. In Figure 5, we explore the implications of this result with representative numbers for a small country in Sub-Saharan Africa. We standardize the number of births averted so that 100 is the maximum value. We assume a fixed population policy budget that is just sufficient to finance secondary education for all young women in the relevant age cohort. We divide the budget between family planning and female education, using representative costs per birth averted for the two options. We start by allocating the entire budget to family planning, and then progressively reallocate to female secondary education. As this increases female secondary enrollment, the cost per birth averted in family planning decreases (per Table 4). The combined effect of increased schooling and higher family planning productivity increases births averted from the initial level of 55 until the maximum of 100 is reached at a 65% allocation to female education. Then diminishing returns set in, and averted births decline progressively to 70 at a 100% allocation to female education. For this case (results will vary for different country settings), more births are averted by focusing solely on education than on family planning. But Figure 5 makes it clear that a sole focus on either program is unwise, because a combined program is significantly more productive. Births averted translate directly to CO2 emissions averted in our approach, so the vertical axis in Figure 5 also tracks CO2 emissions averted (standardized to 100 at the maximum value).

6. A Common Agenda?

The results in Section 5 suggest that female education and family planning are complements for one another and serious competitors for the international resources that will be allocated to carbon emissions mitigation. In the case of female education, recent work by one of the authors with Blankespoor, et al. (2010) also suggests an important role in adaptation to climate change. Our research suggests that female education is a major determinant of resilience in the face of weather-related shocks that are likely to increase with global warming. Using an econometric analysis of historical losses from weather-related shocks, we find that expanding women's education faster than currently-projected trends would prevent many thousands of deaths from floods and droughts, and hundreds of millions of cases of weather-related losses related to injuries, homelessness and other forms of deprivation. Family planning may also play a significant role in this context, particularly through services that focus on maternal and child health. As Oxfam (2008) and DFID (2009) have recently noted in major reports, women and children suffer far more deaths and injuries from weather disasters than men.

To assess the potential level of assistance needed to support expanded population policies, we project the number of women who are likely to remain unserved by education or family planning, and the unit costs of providing these services. To forecast future school-age females who will not be enrolled in primary or secondary education, we develop projections from the econometric results reported in Table 3; the UN's Medium Variant projections for school-age female population cohorts, the total fertility rate and life expectancy; and gdp projections from integrated assessment models reported by Hughes (2009) and employed for a similar exercise by Blankespoor, et al. (2010). We have already presented our estimates for expenditures per pupil in Section 4.5 above. We multiply projected females who will not attend primary or secondary school by projected expenditures per pupil to obtain estimates of future spending deficits for female education.

We develop comparable estimates for family planning in several steps. To project the unit cost of family planning, we re-estimate the equation reported in Table 4 with a different dependent variable: family planning cost per woman served, from the survey database assembled with the support of AGI (2000). The results are reported in Table 6. As in Table 4, both the size of the fertile-age female population and the secondary enrollment rate are highly significant. We also find significant regional differences (captured by the regional dummy variables), which we incorporate into the projections.

To project the percent of fertile-age women not served by family planning, we perform fixed-effects estimation on panel data from MDG (2009).[12] We limit our selection of potential determinants to the available projection variables: the total fertility rate and the size of the fertile-age female population from the UN's Medium Variant Projections; female educational enrollment rates from our own projection work, based on the previously-discussed econometric augmentation approach; and income per capita from Hughes (2009). Among the variables tested, only the total fertility rate is significant in fixed-effects estimation. This imposes a much stricter test than cross-sectional correlation exercises, because it measures the effect of changes in the independent variables on changes in the dependent variable while controlling for unobserved country effects. Table 7 reports our result, which indicates a very powerful association between the incidence of unmet family planning needs and the total fertility rate. Our panel estimation includes fixed effects for countries and 18 global sub-regions. We have included the latter to improve projection accuracy for countries that have no reported observations in the MDG (2009) database. We include the fixed-effects estimates for sub-regions represented in the data.[13]

Using the estimate in Table 7 and projected total fertility rates from the UN's Medium Variant population forecast, we project the percentage of fertile-age women unserved by family planning in each sample country. We multiply this percentage by the projected number of women in the fertile-age cohort to obtain our estimate of total women unserved by family planning. Then we multiply by projected unit family planning costs to obtain the projected spending deficit in each country.

We report the results of our exercise for all developing countries in Table 8. We include projections for school-age females not in primary or secondary school; the % of school-age females not in school; additional resources needed to reach 100% enrollment; fertile-age women not served by family planning; women not served as a % of all fertile-age women; and additional resources needed to extend family planning to all women. As we have previously noted, our projections reflect a view of the future that is reasonably optimistic. Despite continued population growth in many poor countries, the projected percentage of school-age females not attending primary or secondary school falls from

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[12] The estimation exercise for unmet needs for family planning draws on data from MDG (2009), series 764: Unmet need for family planning, total, percentage.

[13] We do not report country fixed-effects in Table 7, since they would fill pages of text.

30% in 2000 to 10% in 2050. The projected percentage of fertile-age women not served by family planning falls from 13% in 2000 to 8% in 2050. But these percentages, applied to very large numbers of women, still produce large projections of unmet need. Even in 2050, our projections indicate over 70 million school-age women not attending school, and over 120 million not served by family planning.

When combined with our unit cost projections, these numbers yield large estimated shortfalls. From a $21.7 billion annual shortfall in 2000, the education spending deficit grows to $28.6 billion in 2050. This occurs despite a fall in females not attending school, because projected unit schooling costs grow proportionally with income per capita. The projected need for additional family planning services is also quite significant: $2.7 billion annually in 2000, and $800 million in 2050. Here it is useful to note why the family planning expenditure deficit falls faster than the number of unserved women. As we report in Table 6, the female secondary enrollment rate is a highly significant determinant of the unit cost of family planning. The secondary enrollment rate grows rapidly in our projections, which reduces the unit cost of family planning.

Our results are sobering, because they suggest large expenditure deficits for female education and family planning into the foreseeable future, despite major ongoing efforts to finance these activities. Few would doubt that they are critical for sustainable development, so budgetary limitations provide the only credible argument against extending them to all women in developing countries. Current limitations are dictated by opportunity costs, since other traditional development needs are also pressing.

With the advent of strong concern about global warming, modification of this traditional calculus may be warranted. On the carbon mitigation side, our results suggest that both female education and family planning are highly cost-competitive with almost all of the existing options for carbon emissions abatement via low-carbon energy and forestry/agriculture. And, as Blankespoor, et al. (2010) have shown, female education makes a highly significant contribution to resilience in the face of climate shocks. Given these findings, the moment seems right for a serious discussion of a common agenda for climate policy and population policy. Expanded investments in female education and family planning can make highly cost-effective contributions to carbon emissions mitigation and adaptation to climate change. At the same time, extending female education and family planning to all women in developing countries will require additional financial resources. These could be provided by a modest portion of the international resources that will support carbon emissions mitigation and adaptation to climate change in developing countries.

7. Summary and Conclusions

In this paper, we have investigated the potential roles of family planning and female education in mitigating carbon emissions from developing countries. Both activities make important contributions to sustainable development, but our evidence suggests that millions of women will remain unserved in the coming decades unless additional financial support is forthcoming. Global resources for carbon emissions abatement could provide this support, but donors are unlikely to consider it unless the evidence indicates that family planning and female education are cost-competitive with other abatement options.

Drawing on the most recent information about emissions, program costs and program effectiveness, we develop country-specific measures for carbon emissions abatement costs via family planning and female education. We compare these costs with the costs of numerous technical abatement options that have been assessed by Nauclér and Enkvist (2009). We develop baseline comparative costs using what we consider to be conservative but reasonable assumptions, and then “shock-test” the cost estimates with extreme adjustments for program productivity and costs. We perform two basic sets of calculations – one for countries where we have directly-observed data, and another for a larger set of countries, using regression-based estimates to augment our database. In all cases, our basic conclusion remains the same: The population policy options are less costly than almost all of the Nauclér/Enkvist options in low-carbon energy and forestry/agriculture, and far less costly than the renewable energy options that are receiving the lion’s share of current attention. Our average global results for developing countries are roughly in line with the results reported by Birdsall (1992).

Our country-level analysis provides further evidence on the important role of cost-sensitive allocation in this context. As Figure 4 shows, all of our baseline scenarios highlight dozens of countries whose carbon emissions abatement costs via family planning and female education are far lower than most of the Nauclér/Enkvist options. Choosing the lower-cost population policy option country-by-country results in population policy costs that are significantly lower than nuclear power and the most widely-discussed renewable energy options in 80 of the 88 developing countries in our sample.

When we consider family planning and female education costs in separate baseline scenarios, family planning is lower-cost in 70% of the developing countries in our sample. However, our results strongly indicate that treating the two options as separable is both misleading and suboptimal. We find that female education has a significant, positive impact on the productivity of family planning programs. The clear implication is that dividing the population policy budget between family planning and female education will be more productive than allocating it solely to one activity. The optimal allocation will be sensitive to country conditions, of course, but our results suggest one useful rule of thumb: Greater attention to female education will increase family planning productivity and carbon emissions abatement most rapidly in countries where female schooling rates are particularly low.

In summary, our results suggest that family planning and female education are complementary activities that, jointly or separately, are highly cost-competitive with a broad range of carbon emissions abatement options that are current candidates for mitigation resources in global climate negotiations. Family planning and female education are both critical factors in sustainable development, and they obviously merit expanded support without any appeal to global climate considerations. However, even relatively optimistic assumptions about future progress in family planning and female education raise the prospect of large funding deficits in the coming decades. Under these circumstance, we believe that the evidence is strongly consistent with an allocation of some carbon mitigation resources to the population policy options. The case for female education is also strengthened by its contribution to resilience in the face of the climate change that has already become inevitable.

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Table 1: Education Projections for Females in Sub-Saharan Africa, 2000 - 2050

Year	Net Primary Enrollment Rate	Net Secondary Enrollment Rate	School-Age Females in School (Millions)	School-Age Females Not in School (Millions)	Unit Education Cost ($US)	Current Enrollment Cost ($Millions)	Additional Resources for 100% Enrollment ($Millions)
2000	57	22	48	68	105	5,051	7,165
2010	67	31	73	72	127	9,223	9,123
2020	77	46	110	66	163	17,901	10,800
2030	85	61	147	53	208	30,406	10,920
2040	90	73	174	39	276	47,881	10,753
2050	93	79	191	30	359	68,715	10,827

Table 2 : CO2 Abatement Opportunities Through 2030 (Nauclér and Enkvist, 2009)

Abatement Opportunities	Range Max Tons Abated (Gt)	Range Outer-Bound Cost ($/Ton CO2)	Energy Efficiency	Low-Carbon Energy	Forestry, Agriculture
Lighting – switch incandescent to LED	5	-130	X		
Residential electronics			X		
Insulation retrofit (commercial)		-100	X		
Residential appliances			X		
Motor systems efficiency		-90	X		
Retrofit residential HVAC			X		
Cropland nutrient management		-80			X
Tillage and residue management		-70			X
Insulation retrofit (residential)		-50	X		
Cars full hybrid		-40	X		
Clinker substitution by fly ash		-30	X		
Waste recycling	10	--20	X		
Electricity from landfill gas				X	
Efficiency improvements other industry		-10	X		
Rice management		-5			X
1st generation biofuels	15			X	
Small hydro				X	
Reduced slash and burn ag conversion		5			X
Reduced pastureland conversion					X
Grassland management	20				X
Geothermal		10		X	
Organic soil restoraction					X
Building efficiency (new buildings)			X		
2nd generation biofuels				X	
Degraded land restoration		15			X
Pastureland afforestation	25				X
Nuclear				X	
Degraded forest reforestation		20			X
Cars plug-in hybrid	30		X		
Low penetration wind		25		X	
Solar CSP				X	
Solar PV		30		X	
High penetration wind	35			X	
Reduced intensive agriculture conversion		40			X
Power plant biomass co-firing		50		X	
Coal CCS new build		60		X	
Iron and steel CCS new build	38	70		X	
Coal CCS retrofit				X	
Gas plant CCS retrofit		90		X	

Table 3: Female Education, Fertility, Life Expectancy and Income

	(1) Total Fertility Rate	(2) Logit Net Female Primary Enrollment Rate	(3) Logit Net Female Secondary Enrollment Rate
Net Female Primary Enrollment Rate	-0.010		
	(5.89)**		
Net Female Secondary Enrollment Rate	-0.030		
	(19.68)**		
Life Expectancy	0.023	0.092	0.051
	(4.72)**	(3.95)**	(5.08)**
Log GDP Per Capita	-0.158	0.159	0.718
	(2.55)*	(0.78)	(6.91)**
Total Fertility Rate		-0.309	-0.556
		(3.51)**	(11.86)**
Constant	6.311	-3.276	-4.454
	(8.85)**	(1.91)	(5.70)**
Observations	978	932	727
R-squared	0.99	0.87	0.98

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 4: Determinants of Family Planning Cost Per Birth Averted

Dependent Variable: Log Cost Per Birth Averted

Log Fertile-Age Female Population	-0.230 (2.81)**
Net Female Secondary Enrollment Rate	-0.016 (3.29)**
Sub-Saharan Africa	1.712 (2.08)*
East Asia/Pacific Islands	2.781 (3.24)**
Eastern Europe/Central Asia	1.831 (1.62)
Latin America/Caribbean	2.197 (2.70)**
Middle East/North Africa	2.416 (2.82)**
South Asia	2.910 (3.25)**
Constant	6.897 (4.83)**
Observations	67
R-squared	0.32

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 5: Overall Costs: Five Scenarios

FP = Carbon Emissions Abatement Cost for Family Planning
ED = Carbon Emissions Abatement Cost for Female Education
H = Houghton Emissions Estimate for Deforestation
C = de Campos Emissions Estimate for Deforestation

			$/Ton of CO2 Abated			
Unit Cost	Deforestation	Emissions Intensity	Directly Observed	Regression Augmented	Augmented FP Only	Augmented ED Only
Min (FP, ED)	Mean (H,C)	Baseline	3.8	3.4	4.3	8.9
Min (FP, ED)	Min (H,C)	Baseline	4.3	3.9	4.7	11.4
Min (FP, ED)	Max (H,C)	Baseline	3.6	3.1	4.1	7.9
Min (10*FP, ED)	Mean (H,C)	Baseline	29.0	9.3	42.7	8.9
Min (FP, ED)	Mean (H,C)	0.25*Baseline	15.3	13.5	17.1	35.6

Table 6: Determinants of Family Planning Cost Per Woman Served

Dependent Variable: Log Family Planning Cost Per Woman Served

Log Fertile-Age Female Population	-0.226 (2.77)**
Net Female Secondary Enrollment Rate	-0.018 (3.74)**
Sub-Saharan Africa	2.561 (3.12)**
East Asia/Pacific Islands	2.646 (3.09)**
Eastern Europe/Central Asia	2.351 (2.08)*
Latin America/Caribbean	2.755 (3.39)**
Middle East/North Africa	2.901 (3.40)**
South Asia	2.844 (3.18)**
Constant	4.545 (3.19)**
Observations	67
R-squared	0.44

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 7: Unmet Needs for Family Planning
Dependent Variable: Percent of Women Unserved by Family Planning

Total Fertility Rate	5.294
	(7.75)**
North Africa	2.953
	(1.03)
Sahelian Africa	9.601
	(2.28)*
Coastal West Africa	8.755
	(2.03)*
Central Africa	-9.007
	(2.04)*
East Africa	2.440
	(0.64)
Southern Africa	16.080
	(4.14)**
Madagascar	2.253
	(0.61)
Indian Ocean Islands	-1.723
	(0.56)
Middle East	0.138
	(0.05)
Western Asia	5.055
	(1.35)
Southern Asia	10.579
	(2.82)**
Southeast Asia	-2.369
	(0.77)
Caribbeam Islands	-2.509
	(0.67)
Central America	-5.871
	(1.55)
Andean South America	6.430
	(2.06)*
Northern South America	7.923
	(2.09)*
Eastern Europe	-4.881
	(1.30)
Western Europe	9.717
	(2.55)*
Constant	-4.355
	(1.65)
Observations	204
R-squared	0.94

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 8: Additional Resource Needs for Female Education and Family Planning: 2000-2050

Year	School-Age Females Not in School (Millions)	% of School-Age Females Not in School (Millions)	Additional Resources for 100% Enrollment ($Millions)	Women Not Served by Family Planning (Millions)	Women Not Served as % of Fertile-Age Women	Additional Resources for Service Extension ($Millions)
2000	216	30	21,735	145	13	2,669
2010	180	24	23,143	148	11	1,853
2020	152	20	25,150	144	10	1,453
2030	122	15	26,014	138	9	1,132
2040	94	12	26,801	130	9	913
2050	74	10	28,642	127	8	809

Figure 1: Regional Sources of Global Warming

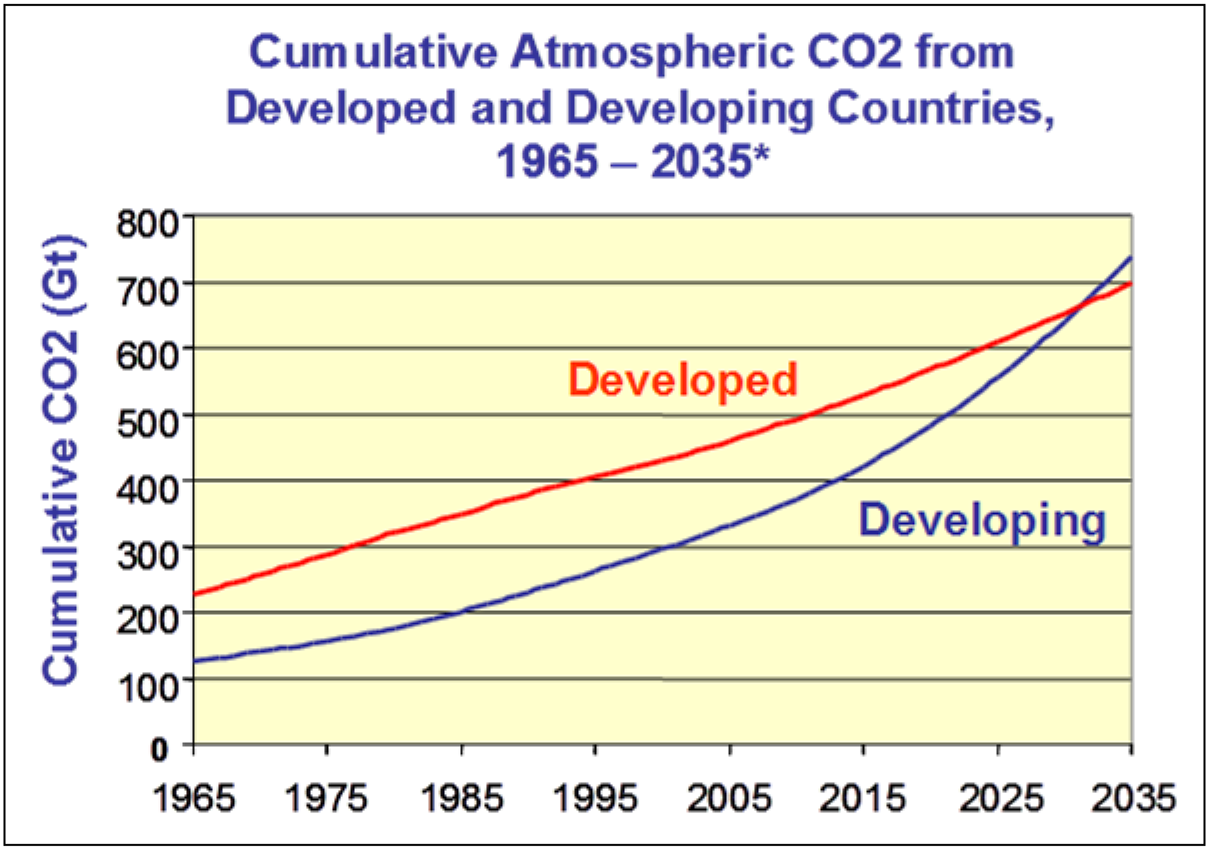

Figure 2: Current vs. Projected Emissions

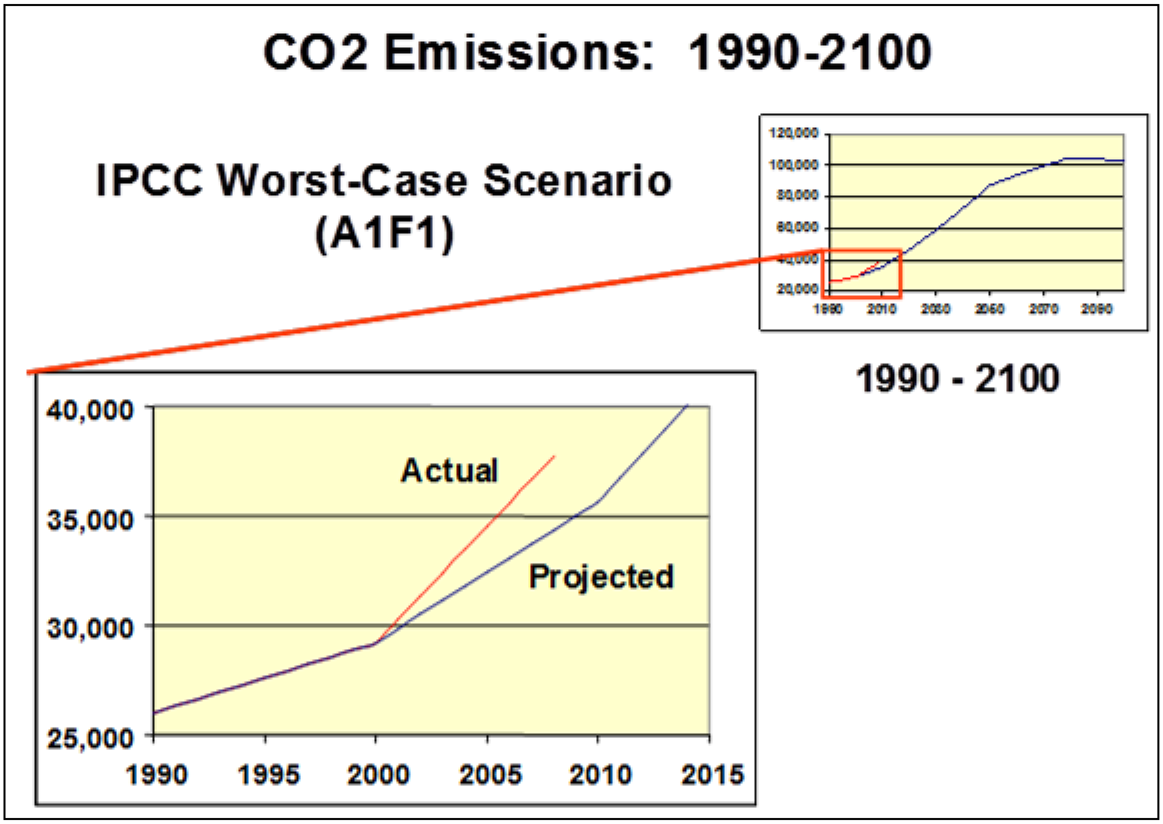

Figure 3: Projected Impact of Climate Change on Agricultural Productivity

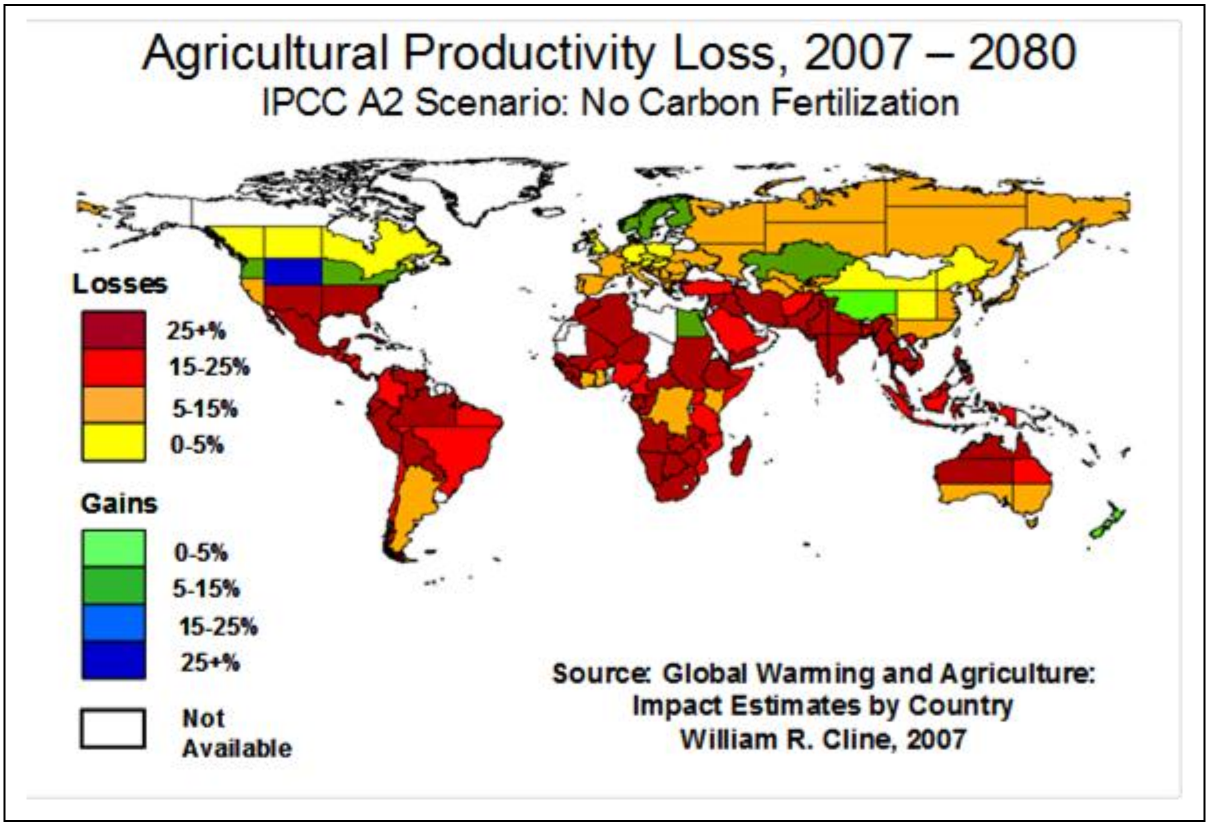

Figure 4: Comparative Costs at the Country Level

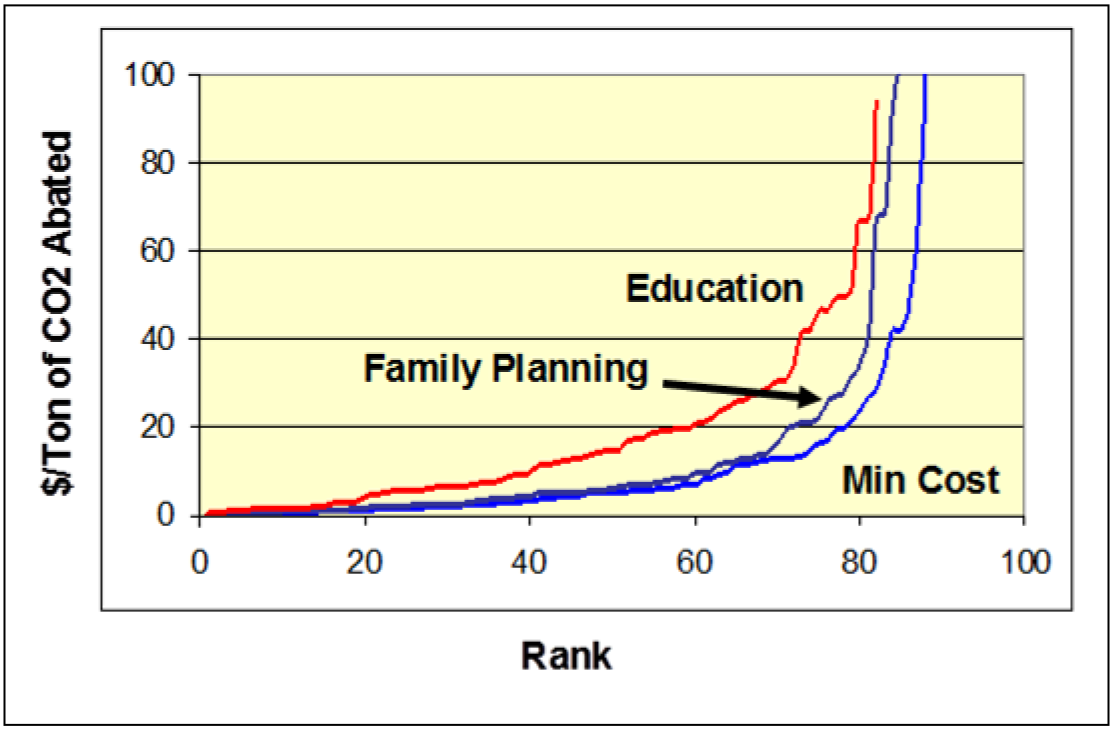

Figure 5: Optimal Allocation of the Population Policy Budget: Hypothetical African Country Case