

Climate Risk Management for Development: Economic Considerations A Concept Paper for the Stern Review

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It is widely recognized that climate variability impacts development, and that climate change poses serious risks to, and threatens to derail current and future development. A recent World Bank assessment (2004) demonstrated that the costs of flood and drought in Kenya as a result of the La Niña drought of 1998-2000 and the El Niño floods of 1997-98 were economy and society-wide³. Climate variability plays a major role in agrarian-dominated economies, such as Ethiopia, where economic growth and food imports have been shown to closely track variations in rainfall (Grey and Sadoff, 2005). Assessments such as these, and many others, have helped to build up the necessary burden of evidence to effectively end any debate: climate matters in development.

But what to do about it? Now that climate is emerging onto the development agenda, it is becoming increasingly obvious that there is no standard methodology, or consensus strategy to adapting to climate variability and change. There is a tendency to focus on coping with current climate variability, due to the uncertainty and long-term time frame of climate change forecasts. Coping with climate variability requires that climate information be integrated into development planning and practice—for both operational and strategic time frames. As is noted in a recent analysis designed to identify the gaps in bringing climate information into development in Africa (IRI, 2006), the problem in essence, is one of “market” atrophy: negligible demand [for climate information] coupled with inadequate supply of climate services for development decisions. Essentially, we need to be able to demonstrate the economic benefits, and/or tradeoffs with development, of choosing to incorporate climate information into development projects.

The purpose of this concept paper is to outline a methodology for incorporating development and climate accounts into the benefit cost assessment of projects that have a primary development (or climate) purpose, but which create benefits related to the other purpose. This methodology is an extension of, and is consistent with the framework that Mac Callaway has been working on since about 1998. The actual genesis of this framework owes the most to Fankhauser (1997). Callaway developed this work in several different directions to tie it together with adjustments to climate variability and to incorporate risk and uncertainty (Callaway et al. 1998, Callaway, 2003, 2004a and 2004b). Since then, we have been members of a group that developed a hydrologic-economic model and have used the model to apply the framework to climate change and adaptation in the Berg River Basin of South Africa (Nkomo et al. 2006). We will use the

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³ The resultant costs of the impacts of the drought and flood were 11 and 16% of GDP, respectively

model in this concept paper to illustrate how one can decompose the costs and benefits of development (or climate) projects into development and climate accounts.

Decomposing Adaptation to Development and to Climate Change

There has been a lot of talk about “climate and development” recently, most of it relatively “soft”. We have nothing substantive to add to that debate, yet. What we do want to do is to extend our earlier quantitative framework to show how to decompose the benefits and costs of projects with both climate and development impacts into different accounts. We also provide an example of how this can be done from some of our recent empirical work.

In our work on the Berg River basin in the Western Cape region of South Africa, we showed that in order to accomplish such decomposition, one has to address two issues:

- Separating the effects of development from the effects of climate change on economic welfare in the reference case(s) used in the analysis, and
- Separating the net benefits⁴ of adapting to development from the net benefits of adapting to climate change.

The illustrative example we will provide here involves building a water supply reservoir (The Berg River Dam) in the river basin where:

- Water demand has been growing rapidly and is projected to continue due to urban development in and around Cape Town,
- There have been a series of unusually dry periods in the last ten years,
- The climate changes predicted for the region are adverse, and
- The competition between irrigated agriculture and municipal water supply is increasing.

Table 1 shows one way of accomplishing the climate and development decompositions. To describe how we undertook the two sets of welfare decompositions in this table we start with the notion that welfare in the basin can be characterized and simulated through the objective function, $W[C_i, D_j, K(C_0, D_j)]^5$. This function shows that basin welfare depends on the both the climate and development states, C_i and D_j and on the amount of water storage capacity in the basin K , which is also a function of the climate and the state of development. Other things being equal, as climate change reduces runoff there is a need for additional water storage capacity and, as water demands increase due to development, there is also a need for more water storage.

The welfare estimates that appear in each cell are the present value of the net returns to water over 30 years, discounted at 6 percent, generated using **BRDSEM (Berg River Dynamic Spatial Equilibrium Model)**, the model we developed for the Berg River Basin. This is a hydro-economic model patterned after the models developed by Hurd, et al.

⁴ We use the term net benefits to account for the sum of project benefits minus costs, since the same accounting framework applies to both benefits and costs.

⁵ See the Technical Appendix for brief definitions for the benefit and cost terms based on this objective function developed in previous work by Callaway et al. (1998) and Callaway (2003, 2004a and 2004b).

(1999, 2004) to assess the economic impacts of climate change in selected river Basins in the US. However, BRDSEM was designed specifically to assess the benefits and costs of optimally adapting to climate change through specific adaptation measures introduced into the model. The model is driven by downscaled monthly temperature and precipitation data from climate scenarios for selected GCMs and this is converted into monthly runoff, reservoir evaporation and crop water use factors using Watbal (Yates, 1996). One of the key aspects of climate forecasts is their uncertainty, which can be addressed to some degree through probabilistic representation of climate outcomes. However, in order to keep this analysis simple, we focus on one climate forecast realization, the CSIRO Mk2 model, SRES B2 realization, for the ‘near future’ time period⁶. These estimates are illustrative only.

In this analysis, development is simulated by shifting the urban water demand curves in the BRDSEM model to the right by about 3 percent per year to reflect a continuation of current population growth. Climate change is simulated by a change from the current climate as simulated by the CSIRO GCM to the SRES-B2 near future climate scenario.

This table contains three panels, each containing two by two cells. The first panel shows the *ex ante* partial and full adjustment to future development, holding climate constant. The second panel shows the *ex ante* partial and full adjustment (adaptation) to climate, holding development constant. Finally, the third panel shows the *ex ante* partial and full adjustment of adapting to climate change, after adjusting for development⁷.

Why so many panels? If we look, first, at the initial level of welfare in the basin for the existing climate in the upper left cell of the first panel (51.934 billion Rand) and then, last, at the level of *ex ante* welfare after all of the adjustments to climate change (57.040 billion R), we see that there has been an estimated increase in welfare of 5.106 billion Rand. How did that happen? Basically, the answer is that simulated welfare in the basin increases substantially due increases in water consumption as urban population increases. Adjusting to development, optimally, by increasing storage capacity further increases welfare, but not by much. When a simulated change in climate is imposed on top of this demand growth, welfare decreases due to the adverse effects of climate change. However, the climate change damages are not large enough to offset the increase in welfare due to development and adjusting to it. Building additional reservoir storage capacity to adapt to climate change further offsets some of these damages, so the net result after all adjustment is positive compared to the Base Case. But the question remains: how to decompose all these effects?

⁶ The near future time period is 2010-2039

⁷ The results are sensitive to the order of adjustment, starting with development or climate and then adding the second adjustment.

TABLE 1. Ex Ante Framework for Decomposing Effects of Development and Climate and Net Benefits of Adjusting to Development and Climate, Measured by Simulated Net Returns to Water in the Berg River Basin in Millions of Rand (over 30 years discounted at 6%)		
Adjustments to Development and Reservoir Capacity (10^3 m^3)	Development States (Holding Climate at C_0)	
	No Development D_1	3% Development D_1
Adjustments to D_0 $K(C_0, D_0)=0$	Optimal adjustment to no development $W[C_0, D_0, K(C_0, D_0)]$ 51,934	Partial adjustment to 3% development $W[C_0, D_1, K(C_0, D_0)]$ 62,501
Adjustments to D_1 $K(C_0, D_1)= 75.3$	Partial adjustment to no development $W[C_0, D_0, K(C_0, D_1)]$ 51,789	Optimal adjustment to 3% development $W[C_0, D_1, K(C_0, D_1)]$ 62,747
Adjustments to Climate and Reservoir Capacity	Climate States (Holding Development at D_0)	
	Existing Climate C_0	Climate Change C_1
Adjustments to C_0 $K(C_0, D_0)=0$	Optimal adjustment to existing climate $W[C_0, D_0, K(C_0, D_0)]$ 51,934	Partial adjustment to climate change $W[C_1, D_0, K(C_0, D_0)]$ 45,592
Adjustments to C_1 $K(C_1, D_0) =75.0$	Partial adjustment to existing climate $W[C_0, D_0, K(C_1, D_0)]$ 51,848	Optimal adjustment to climate change $W[C_1, D_0, K(C_1, D_0)]$ 46,898
Adjustments to Development and Climate and Reservoir Capacity	Change in Climate States (After Adjusting for Development)	
	C_0, D_1	C_1, D_1
Adjustments to C_0 $K(C_0, D_0)=75.3$	Optimal adjustment to 3% development $W[C_0, D_1, K(C_0, D_1)]$ 62,747	Partial adjustment to climate change, given development adjustment $W[C_1, D_1, K(C_0, D_1)]$ 56,763
Adjustments to C_1 $K(C_1, D_1)=124.6$	Partial adjustment to 3% development and existing climate $W[C_0, D_1, K(C_1, D_1)]$ 62,701	Optimal adjustment to development and climate change $W[C_1, D_1, K(C_1, D_1)]$ 57,040

In the first panel, if we consider only two development states (no growth and 3 percent growth), then movement from the upper left to the upper right cell characterises partial adjustment to development. The difference between the welfare levels in the two represents the increase (or decrease) in welfare due to development, without adjusting to

it, holding climate constant. This effect is large: simulated development, alone, increases *ex ante* welfare by $62,501 - 51,934 = 10.567$ billion Rand, even when no additional water storage capacity is developed, simply because more water is being consumed⁸. If we move to the lower right cell, this represents the situation in which basin planners have optimally adjusted the reservoir capacity to account for future development, holding climate constant. This effect is relatively small: when the optimal level of storage consistent with three percent growth is developed (75.3 thousand cubic meters of storage), *ex ante* net welfare only increases by a small amount, $62,747 - 62,501 = 246$ million Rand. These are the net benefits of building a reservoir to cope with development, only. Finally, if we sum up these two effects, the combined *ex ante* net benefits of development and adjusting to it, holding climate constant at C_0 , are $10.567 + .246 = 10.813$ billion Rand.

The fact that building a dam to cope with development produces only small net benefits is an empirically important result. There are two reasons for this result:

1. As water consumption increases, additional increments of storage capacity produce physically smaller amounts of average annual yield from the Berg River Dam, and
2. The marginal benefits of increasing storage are not high enough to justify the high marginal storage costs of additional increments of capacity.

The second panel captures the *ex ante* adjustment to climate change, holding development at the no development level of urban water demand growth. If the climate changes and adaptation to it consists only of short-run (i.e., partial) adjustments, a movement from the upper left to the upper right cells, welfare is reduced by $45.592 - 51.934 = -6.342$ billion Rand. This amount represents the *ex ante* value of climate change damages⁹. However, if planners adapt to climate change in the lower right cell by building the optimal capacity reservoir consistent with C_1 , without any development, (or 75.0 million cubic meters), the *ex ante* net benefits of adaptation are substantial, equal to $46.898 - 45.592 = 1.306$ billion Rand. The *ex ante* imposed climate change damages after full adjustment are, turn, the sum of the climate change damages and the net benefits of adaptation, or $46.898 - 51.934 = -5.036$ billion Rand. Thus, the reservoir avoids 1.306 out of 6.342 billion Rand, or roughly 21 percent of climate change damages.

The contrast between the ability to adjust “optimally”¹⁰ to development (holding climate constant) and the ability to adjust optimally to climate change (holding development constant) is important. The fact that the optimal capacity required to make both adjustments is about 75 million cubic meters is accidental, but fortunate, as it allows us to compare the net benefits of the two adjustments, holding capacity constant (3.28 vs. 13.82 Rand/cu meter storage capacity for development and climate change, respectively). These differences reflect the different effects of development and climate on the

⁸ While welfare increases, this growth in urban demand also increases competition for water in the basin; water prices increase; and agricultural water use to irrigate high value export crops is reduced.

⁹ See the technical appendix for definitions of climate change damages, net benefits of adaptation and imposed climate change damages.

¹⁰ Optimally means in terms of economic efficiency criteria, only.

relationship between additional increments of storage capacity and average annual reservoir yield. Given the development and climate scenarios we used in this analysis, increments of capacity added to meet development demands translate into much smaller additions to reservoir yield than is the case with the increments of capacity added to avoid climate change damages. What we are saying, here, is that in this basin at least dam building is more effective at adjusting to climate change than development. On the other hand, dam building only avoids 21 percent of climate change damages.¹¹

The first two panels in Table 1 represent “partial” decompositions in which we hold either development or climate constant and vary the other. Now, in the final panel, we look at adaptation to climate change after the adjustment to development has occurred. The cell in the upper left in this panel is the same as the lower right in the first panel, reflecting that the adjustment to development has taken place (only in a planning sense, not implementation). If we partially adjust to climate change after we have adjusted to development, as reflected in the upper right cell of this panel, then there is an estimated decrease in *ex ante* welfare of $56.763 - 62.747 = -5.984$ billion Rand in climate change damages. In full adjustment to both factors, as depicted in the bottom right cell, the optimal level of investment in water storage is 124.6 million cubic meters and the *ex ante* net benefits of adapting to climate change are $57.040 - 56.763 = 0.277$ billion Rand. Finally, the total difference between basin welfare after the final adjustment to climate, or the imposed damages of climate change, are $57.040 - 62.747 = -5.707$ billion Rand.

The results of Table 1 are summarised in Table 2. Each row in the table summarises the results in the corresponding panel in Table 1. The first column represents a movement from the upper left to the upper right cell in each panel, or partial adjustment to climate change, when only short-run measures are used to adapt to climate change. The second column represents the optimal or full adjustment to climate change by changing the storage capacity of the Berg River Dam, through a movement from the upper right to the lower right cell in each panel. The final column is the sum of the two adjustments, which can be calculated as the difference between the lower right cell and the base case (upper left) in each panel.

Decomposition Components	Type of Adjustment		
	Partial Adjustment	Optimal/Full Adjustment	Combined Adjustment
Partial development effect (Panel 1: Development only)	10.567	0.246	10.813
Partial climate effect (Panel 2: Climate change only)	-6.342	1.306	-5.036
Climate adjustment added to Development adjustment (Panel 3)	-5.984	0.277	-5.707

¹¹ Changing the allocation system to a market-based system produces higher net adaptation benefits, but we do not have space to compare these options (Nkomo, et al. 2006).

Table 2 tells a consistent story. The partial effect of increasing urban water demand on welfare (row 1) in the basin is positive, both when water managers and water users can only adjust to it in the short run (10.567 billion R) and when water storage capacity can be added (0.246 billion R). Consequently, the combined adjustment (10.813 billion) is also positive. The partial effect of climate change (row 2), on the other hand, is negative both when agents can only adjust partially (climate change damages of –6.342 billion Rand) and fully (net adaptation benefits of 1.306 billion Rand) and in combination (imposed climate change damages of –5.036 billion Rand). The final effect (on top of development in row 1) in row 3 show that, after the adjustment to development, climate change causes damages on the order of – 4.98 billion Rand, while adapting to climate change, once the adjustment to development has occurred, yields relatively small net adaptation benefits of 0.277 billion Rand. Thus, the imposed damages of climate change of adapting to climate change after adjusting to development are still – 5.707 billion Rand. The total change in welfare, from start to finish is $10.813 - 5,707 =$ an increase of 5.106 billion Rand.

Thus, the net benefits of adapting to climate change become smaller after adjusting for development. Both development (on the water demand side) and climate change (on the supply side) make it more difficult to respond to the other, both partially and fully. This has to do with the effects that increasing water demand and reducing water supply have on the yield-storage relationship, with larger and larger increments of storage required to provide an additional unit of yield. At the same time, the marginal cost of additional storage increases, and these two factors work against each other.

This does not mean that good development policy is not good climate policy. Rather, it means that at least for the option of adding storage capacity in this basin, for this climate scenario:

- The benefits of development and adjusting to it are greater than the damages of climate change plus the benefits of adapting to it, and
- Adjusting to development adversely impacts the ability to adapt to climate change, producing small net benefits in relation to climate change damages.

Technical Appendix

The following benefit and cost measures have been developed in previous work, using the notation in this paper:

Climate change damages = the *ex ante* economic value of the damages caused by climate change taking into account partial adjustments to climate variability =
 $W\{C_1, D_j, K(C_0, D_j)\} - W\{C_0, D_j, K(C_0, D_j)\} \leq 0.$

Net benefits of adaptation = the *ex ante* net benefits of avoiding climate change damages taking into account full adjustment to climate change =
 $W\{C_1, D_j, K(C_1, D_j)\} - W\{C_1, D_j, K(C_0, D_j)\} \geq 0.$

Imposed damages of climate change = the *ex ante* value of the climate change damages that can't be avoided = $W\{C_1, D_j, K(C_1, D_j)\} - W\{C_0, D_j, K(C_0, D_j)\} \leq 0.$

The ex ante, ex post cost of not planning for climate change that does occur (being cautious) =
 $W\{C_1, D_j, K(C_0, D_j)\} - W\{C_1, D_j, K(C_1, D_j)\} \leq 0.$

The ex ante, ex post cost of planning for climate change that does not occur (being precautionous) = $W\{C_0, D_j, K(C_1, D_j)\} - W\{C_0, D_j, K(C_0, D_j)\} \leq 0^{12}.$

¹² For true “no regrets” measures the cost of precaution will be positive (i.e., have positive net benefits), since the measure by definition will produce net benefits, independent of the climate state.

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