CLIMATE CHANGE IMPLICATIONS FOR WATER RESOURCES PLANNING IN TRANSBOUNDARY WATER SYSTEMS

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According to the Intergovernmental Panel on Climate Change, climate change is likely to have a complex set of impacts on water resources throughout the world (IPCC, 2007b). Warming attributable to rising atmospheric concentrations of greenhouse gases will affect ocean and surface temperatures, precipitation patterns, evapotranspiration rates and the demand for water in agriculture, the frequency and intensity of storms, the timing and magnitude of runoff, and sea level in coastal communities (Frederick and Major, 1997; IPCC, 2007a). Though there has been fairly extensive research aimed at assessing the magnitude of such impacts under different emissions scenarios in the global context and in specific regions (Leavesley, 1999; Arnell, 2004; Milly et al., 2005), little guidance exists on how these effects of global warming should be integrated into planning for new capital-intensive investments in water resources, as well as renewal of old infrastructures (Wood et al., 1997).

This research develops a hydro-economic modeling framework for integrating climate change impacts into the traditional water resources planning problem. This framework aims to explicitly include the numerous impacts of climate change on water resources described above. First, the framework demonstrates how traditional river basin models can be modified to include explicit linkages between, on the one hand, climatic factors (such as temperature and precipitation) – specified based on General Circulation Model or Regional Climate Model projections – and on the other, the parameters they influence: net evaporation from storage structures, stream flows, water demands, and flood and drought risks throughout the system. The modeling framework thus allows for comparison of system outputs in physical terms under historical and changed conditions.

Next, using this framework, we show that the question of climate change requires use of a fundamentally different approach for economic appraisal of new infrastructures. Traditional economic appraisal methods for such projects seek to quantify to the extent possible all of their economic costs and benefits assuming that historical conditions will be maintained over the planning horizon. The methods then use these estimates to determine the expected value of net benefits from the investments, as well as the uncertainty associated with the calculations. Unfortunately, the climate change problem does not allow calculation of expected net benefits, because the probabilities associated with different climate futures are unknown. The conceptual problem with conducting such traditional economic analysis emerges from several aspects of the climate change problem, most notably that: a) accurate prediction of future emissions levels is very difficult, b) the ranges of most changes caused by greenhouse gas emissions are highly uncertain, and c) the impacts themselves are likely to vary regionally and temporally in ways that are not very well understood and/or predicted using climate models available today.

In effect, the very fact that the baseline against which new infrastructures must be assessed is evolving presents complex challenges to the planner. It is no longer sufficient to evaluate project performance in parallel with historical system performance, since the historical system itself is changing. Instead, a different approach is needed that looks at the economic results of adding new infrastructures under a series of different possible climate futures, each of which can be assessed independently using simulation techniques. For each of the future climate scenarios considered, the planner should conduct repeated experiments using synthetic series' of inflows generated using existing methods from the field of hydrology, which generate numerous sets of outcomes at different points in a river basin over the time horizon of interest (i.e. evaporation losses, hydropower generated and carbon offsets, water available for irrigation, flood risk probabilities, etc.) (Frederick et al., 1997; Stakhiv, 1998). The outputs from these simulations can then be used to construct statistical distributions of physical outcomes which, when combined with likely distributions of economic parameters, allow economic assessment of the project in question under the given scenario. By applying these methods across a range of climate scenarios, the planner can then judge the relative investment risks associated with uncertainty about climate change and uncertainty about the parameters which influence system performance. In some cases, investments in new or modified infrastructures may be justified based on their contributions to economic well-being from use of a river that is enhanced in the future (as in the standard appraisal problem); in others, they may be warranted if they sufficiently reduce vulnerability in a future world where the well-being associated with uses of the river basin substantially declines (the adaptation problem).

This paper develops the framework described above in detail and illustrates its use with a stylized application to the Nile River, a complex, transboundary river basin system. The economic value of a potential development project important from a regional context in the Blue Nile canyon is assessed, and the influence of one illustrative climate change scenario on the planning decision is discussed. The Nile Basin is an interesting case study for several reasons. First, much of the Blue Nile basin upstream of Egypt and Sudan remains unregulated and undeveloped, and there appear to be very attractive sites for large water resources infrastructures at several locations within it (with regards to hydropower potential, surface-to-volume reservoir ratio and low potential for displacement of local livelihoods and households).

Second, there is an opportunity for collaborative planning of water resources investments among Nile countries due to their increasing participation in the Nile Basin Initiative and the potential for system-wide benefits that would result from upstream regulation. Third, initial research on climate change suggests that arid and semi-arid developing countries (such as those which make up the set of Nile riparians) are particularly vulnerable to the impacts of climate change (Conway et al., 1996; Abou-Hadid, 2006; Deressa, 2007; IPCC, 2007a; Strzepek and McCluskey, 2007). New or existing infrastructures may play an important role in adaptation to climate change, via planning considerations such as timing and sizing of investments, as well as management adaptation that alters operation rules and aims at improved coordination among planned and existing infrastructures. Fourth, there is substantial uncertainty concerning how climate change will impact the Nile Basin (Gleick, 1991; Conway and Hulme, 1996; Sayed and Nour, 2006). Our simulation framework for assessing projects thus appears particularly useful.

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