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# To Mitigate or to Adapt: Is that the Question?

## Observations on an appropriate response to the Climate Change Challenge to Development Strategies

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**Abstract**: Climate change is a new and important challenge to development strategies. In light of current literature we provide a framework for assessing responses to this challenge. We conclude that the presence of climate change makes it necessary to at least review development strategies—even in apparently non-climate sensitive and non-polluting sectors. There is a need for *an integrated portfolio of actions* ranging from avoiding emissions (mitigation) to coping with damages (adaptation). Proactive (*ex ante*) adaptation is critical, but subject to risks of regrets when the magnitude or location of damages is uncertain. Uncertainty on location favors non-site-specific actions, or reactive (*ex post*) adaptation. However, some irreversible losses cannot be compensated for. Thus, mitigation might be in many cases the cheapest long-term solution to climate change problems, and the most important to avoid thresholds that may trigger truly catastrophic consequences. To limit the risks that budget constraints prevent developing countries from financing reactive adaptation—especially since climate shocks might erode the fiscal base—"rainy-day funds" may have to be developed within countries, and at the global level for transfer purposes. Finally, more research is required on the impacts of climate change, and on modeling the interrelations between mitigation and adaptation, and on operationalizing the framework.

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Until recently, policymakers and development experts could at least assume that where there was water today, there would still be water in the future. Or that where there was a coastline suitable for a port, that coastline would still be there in the future. In other words, the geographical and physical foundations for development, and for the determination of competitive advantage, were treated as stable and reliable.

This presumption is no longer true, as climate change threatens to bring about important shifts in precipitation and weather patterns, sea-levels, and water flows (IPCC, 2007a), ratcheting up pressure on land and ecosystems (IPCC, 2007b), thereby making previously stable parameters less stable. In fact, the fingerprints of climate change are increasingly evident in changing weather patterns across the globe. From a developing country perspective, climate change is thus yet another important (and new) challenge within which development takes place. It may bring new opportunities, but also many constraints and risks. As such, development and growth will be taking place against a new head-wind.

*The key question for developing countries is the extent to which this new challenge—climate change—will modify the allocation of resources in development strategies.* For a variety of reasons, the international debate on climate change is currently framed around 'reducing emissions', i.e. *mitigation*. Since we all emit greenhouse gases (GHG) into a shared atmosphere, protecting the quality of the atmosphere as a global public good requires global collective action. Developed countries have taken some (modest) emission reduction commitments, and developing countries are now under pressure to commit to emissions targets as well. Developing countries have resisted this call on the grounds that they contributed little to the current concentrations of GHG in the atmosphere, and cannot afford to increase the cost of development given their poverty and low standards of living. Prominent on their agenda, in fact, is 'making their development strategies robust to climate change', i.e. *adaptation*.

We propose a framework for assessing responses to the challenge that climate change poses to development strategies. Using this framework we address the following questions: Is climate change worth revising development strategies? How can one think about the balance between mitigation and adaptation? And how might the balance in this portfolio be affected by the uncertainties about the extent and location of climate damages?

The paper is organized as follows. First, we briefly review the literature on the risks that climate change poses to economic development, and describe the options available to respond. Second, we argue that ***an integrated portfolio of actions***, including both mitigation of and adaptation to climate change is necessary (for both developed and developing countries) because mitigation and adaptation are in general *not* separable, and we review the literature on how to balance this portfolio given the uncertainties about climate damages. Next, we argue that the need for a portfolio remains despite criticisms that mitigation is low priority for development, and that there is no public-sector role in adaptation. On this basis, we finally argue that a broad review of development strategies is warranted. We conclude by discussing some of the limitations of the current literature on the topic, and by identifying areas for further research.

# Setting the Stage: Evaluating the Risks to Economic Development and Identifying the Options

The causal chain linking economic behavior today to economic consequences tomorrow *via climate change* can be summarized as follows: economic activities → GHG emissions → atmospheric concentrations of GHG → climate change → impacts on physical and ecological systems and, finally → impacts on economies and human welfare.

## *Climate Change Threatens Economic Development*

Climate change matters to policy making only if its potential ultimate damages are expected to be significant, i.e., only if the expected *laisser faire* or business-as-usual scenario *with* climate change differs markedly from the expected *laisser faire* scenario *without* climate change. A converging set of data and projections suggest that such a significant difference is in fact likely (see the Intergovernmental Panel on Climate Change recent assessment, 2007a,b). The ultimate damages of climate change encompass both *gradual changes in climatic averages* (mean precipitation, temperature, etc.) and increases in the *variance, frequency and/or magnitude of climatic shocks*, both with potentially significant economic implications.

The estimates of the economic costs associated with climate change impacts focus mostly on gradual changes. Early figures in the mid-‘90s estimated these costs at around 1.5-2.0% of World GDP in

2100 for temperature increases between 2-3°C by 2100 (see Pearce et al., 1996, for a summary). New analysis in the early 2000s found generally lower costs (Mendelsohn et al., 2000, Tol, 2002a,b, Nordhaus and Boyer, 2000). But Stern (2007) has recently reported costs ranging from 5% - 20% annual equivalent loss of World GDP from now to 2200. The changing estimates reflect improvements in data and methods over time (e.g., inclusion of adaptation *and* catastrophes), evolution of scientific views about certain aspects of climate change (e.g., mean temperature increase in 2100 for a given emissions path), and differences in the choice of key parameters (e.g., the value of the pure rate of time preference). Despite the dispersion of the results, there is an emerging consensus that climate change will have a net negative impact on developing countries, that the aggregate impacts of climate change on economic growth can be significant in individual countries (Lecocq and Shalizi, 2007b), and that the impact on specific resources can be high, generating additional tensions where resources availability is already an issue (e.g., Kundzewicz et al., 2007, for *freshwater*).

The development literature shows that climatic shocks (not necessarily due to climate change) have already had large impacts on economic growth in many countries, such as Madagascar, Bangladesh, or Central American countries (IMF, 2003), and play a significant role in explaining cross-country economic differences (Easterly et al., 1993, Collier and Dehn, 2001). This suggests that tomorrow's climate-change induced climatic shocks, which are likely to be larger and more frequent than today's, may affect economic growth further, within the same countries, their neighbors, as well as in others with similar characteristics (Martin and Bargawi, 2004). Though there is no empirical or theoretical consensus on the key mechanisms through which climate shocks have such large impacts on growth, a number of factors, such as the size of climate-sensitive sectors (e.g., agriculture or tourism), the indirect impacts on non-climate-sensitive sectors, rigidities in factor allocation and in price adjustments (Hallegatte et al., 2007), and the strength of institutions and cohesiveness of society (Rodrick, 1999) appear to play an important role.

An increase in the frequency and magnitude of shocks due to climate change would also increase the chance of countries falling into 'poverty traps', or reduce their chances of getting out of them (as a

result of path dependent multiple equilibria combined with stochastic shocks, Azariadis and Stachurski, 2004). Similarly, increasing returns to agglomeration (Fujita et al., 1999) can magnify the national or global consequences for economic growth of localized impacts of climate change on key localities (such as major[1] or coastal cities[2] that constitute national engines of growth) (Huq et al., 2007).

The analysis above thus suggests that climate change is an important enough risk to development that it warrants a response at the national and international level. The rest of the paper aims at providing some views on what that response should be.

## *The Options to Respond: Mitigation, Proactive Adaptation, Reactive Adaptation*

To limit the impacts of climate change on economies, countries can *mitigate* emissions or *adapt* to climate change consequences. Mitigation (M) consists of reducing emissions (or removing GHG out of the atmosphere) at the beginning of the chain to minimize climate change in the first place. By contrast, adaptation (A) consists of responding to climate change impacts at the end of the chain.

For example, shifting from coal- to gas-fired power plants (thereby reducing GHG emissions per kWh produced), developing renewable energy, or reducing deforestation and associated emissions of carbon dioxide are mitigation actions. In the literature, 'mitigation' also encompasses *carbon sequestration* (either biological via photosynthesis, or physical through carbon capture and storage), though sequestration does *not* avoid emissions but removes carbon out of the atmosphere (i.e., it reduces *net* emissions and not *gross* emissions). Relocating people and capital away from new flood-prone areas, shifting to crops that are more resistant to drought, or responding to and rehabilitating areas post natural disasters are all examples of adaptation actions.

In addition, following Smit et al. (2000), we distinguish two forms of adaptation. *Reactive* adaptation (RA) focuses on *coping ex post* with the adverse impacts of climate change, when they occur. *Proactive* (or anticipative) adaptation (PA), on the other hand, focuses on *lowering the costs of coping ex ante*. PA encompasses measures taken in advance to limit the ultimate damages of climate change and/or to reduce the extent of reactive adaptation required when climate change impacts materialize. For

example, evacuating people from a flood-hit area is reactive adaptation, while modifying zoning laws on coasts in anticipation of stronger sea surges is proactive adaptation. Even though proactive adaptation and mitigation are both *ex ante* actions, proactive adaptation only reduces the cost of *ex post* adaptation but not the need for it, because it does not reduce emissions as mitigation would.

As noted by Fankhauser et al. (1998), the distinction between proactive and reactive adaptation is intuitively clear, but difficult to delineate with precision in a dynamic setting. For example, after the heat wave of August 2003 in France, which is estimated to have caused in excess of 11,000 deaths over historical averages, the French government prepared a "Heat Wave National Action Plan" [3] that includes *inter alia* the creation of a national alert system, a strong effort for prevention and information, and a clearer division of tasks among public agencies. This plan was adopted both in reaction to the 2003 heat wave itself (i.e., RA) and in anticipation of future repeat events (i.e., PA)—as such, it is a typical example of *co-evolution* of problems and responses in a dynamic setting.

However, the distinction between proactive and reactive adaptation is important from a policy point of view because the rationale for the two actions are very different. Proactive adaptation (like mitigation) uses resources *now* to prevent possible crisis in the future, while reactive adaptation uses resources to cope with events *at the time they occur*. *The crux of the problem is that, in practice, behavioral changes and policy decisions are often easier to implement once a crisis has occurred than in anticipation of a crisis. But from an economic point of view, examples such as the 2004 Indian Ocean Tsunami or the 2005 hurricane Katrina suggest that the costs of preventive action, e.g., installing early warning systems or fixing dikes, are often lower than the costs of deferred action,*[4] *even when appropriately discounted, thereby making proactive adaptation preferable* (Athukorala and Resosudarmo, 2005, Burby, 2006).

Finally, we use the term 'ultimate damages' (UD) for those damages that would be incurred *in the absence of any policies*—even if some private adaptation is implemented—, and 'residual ultimate damages' (RUD) for those damages that are technically irreversible (e.g., lost species) or economically irreversible (i.e., that may be feasible technically, but are considered too costly, for example, the full restoration of the Everglades ecosystem or the Aral Sea), and 'likely to remain' after all mitigation and

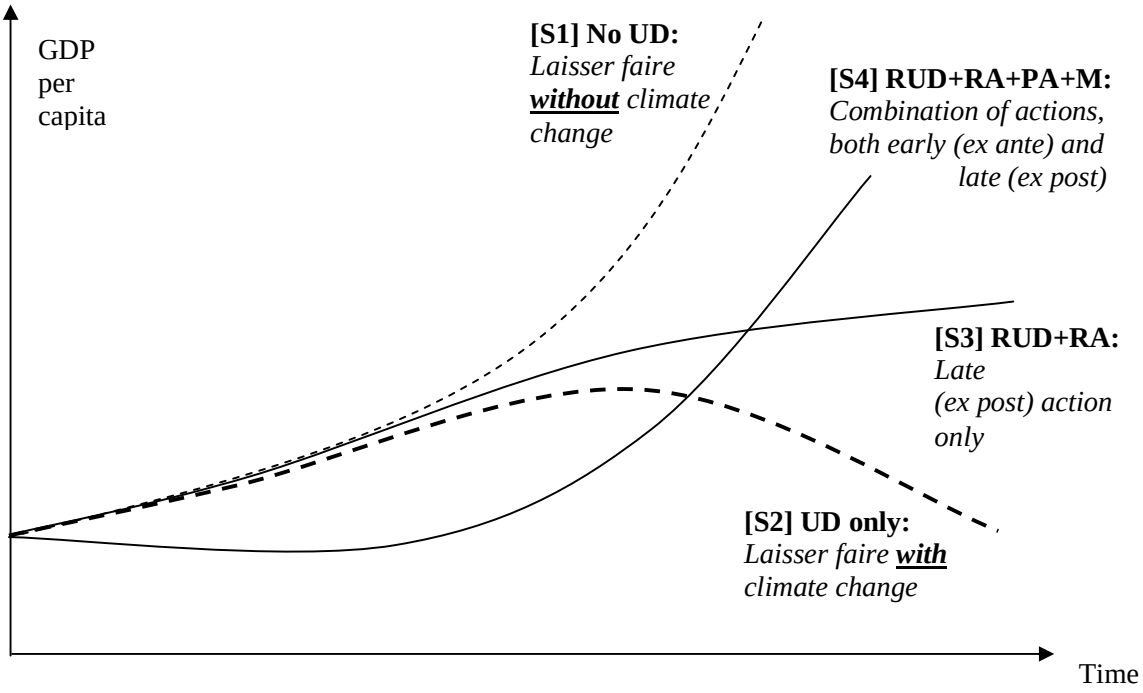
adaptation expenditures have been incurred.

There are thus three main options only to reduce the ultimate damages of climate change: mitigation (*ex ante*), proactive adaptation (*ex ante*) and reactive adaptation (*ex post*).

## *The Appropriate Counterfactual for Evaluating Climate Change Options: No Action and Full Ultimate Damages*

Before choosing among these options, an important methodological point about the appropriate counterfactual must be made. Most assessments of mitigation policies have used as the baseline for ranking options a business-as-usual (BAU) or *laisser faire* growth (scenario S1 in Figure 1) in the *absence* of climate change. Yet the uncertainty about the likelihood of human-induced global warming has been essentially resolved by now. In fact, from many different directions scientific evidence suggests that some degree of climate change is already occurring (IPCC, 2007a). Thus, a *laisser faire* scenario without climate change (S1) does *not* describe any real-world situation anymore. The appropriate counterfactual scenario (to determine the *real opportunity costs*) is now one in which no action whatsoever is taken against climate change; and in which, as a result, the full set of damages associated with climate change are incurred on the whole portfolio of assets (S2).

**Figure 1**: Illustrative growth over time in the *laisser faire* cases *without* climate change [S1] and *with* climate change [S2], and the position of two policy scenarios, one with reactive adaptation only [S3], and the other with a combination of actions [S4], relative to these two counterfactuals




Against the first counterfactual (S1), any policy action against climate change, or any combination thereof, has a *net cost*. In other words, it looks as if any policy action were making the economy worse off. (This is not the case, of course, because even *no* action as in S2 leads to a net cost relative to S1.) However, relative to the *laisser faire* scenario in the presence of climate change (S2), it will be seen that a combination of policy actions (S3) or (S4) might bring *net benefits*.

Worrying about the appropriate counterfactual may seem trivial *if* the ranking of policy options doesn't change. However, the message conveyed will be different depending on how the problem is *framed*: The net benefits of mitigation action will be reported as a *positive* with respect to a counterfactual *with* climate change, and as a *negative* with respect to counterfactual *without* climate change (Mohr, 1995). At a more fundamental level, the set of mitigation options available in the presence of climate change is also likely to be more restricted than the set of options available in the absence of climate

change because the efficiency of mitigation actions and the intensity of climate change are interdependent. This *can* affect the ranking of policy options (and targets).[5] For example, if climate change were not already occurring, investing in hydropower instead of using fossil fuels to generate energy could be a very appropriate mitigation measure in countries with glacial melt, such as Bolivia or Afghanistan. With climate change, however, the glaciers will initially melt faster than historic patterns—thereby generating potentially higher volumes of water and requiring larger or taller dams. But eventually, once glaciers have disappeared there will be insufficient water and some or all the investments could be stranded or wasted, especially if the time-line is compressed due to an acceleration in climate change.[6]

## An Integrated Portfolio of Actions is Needed to Minimize the Climate Bill

The decision problem faced by the international community is to choose the best combination of options (mitigation, proactive adaptation and reactive adaptation) *to minimize the global climate bill*, i.e., the sum of the costs of mitigation, proactive adaptation, reactive adaptation, *and* residual ultimate damages (the latter depending on the levels of mitigation, proactive adaptation and reactive adaptation) through appropriate incentives and transfer mechanisms.

The decision problem is different at the national level because individual countries, whether small or large emitters, have little direct control over total World emissions. This has two critical implications. First, they have to set domestic proactive and reactive adaptation levels *given other countries' mitigation decisions.* Second, their mitigation decisions, for the most part, make sense primarily in the context of global action. Here, however, large and small emitters differ. For countries that are large emitters (such as, China,[7] India, Brazil, Indonesia, Mexico, and a few others among developing countries), domestic mitigation decisions can have direct measurable implications for domestic damages, not just indirect via global collective action. For countries that are small emitters, domestic mitigation decisions will still matter, but only in certain circumstances: For example, if the use of cleaner fuels is also cheaper in the long-run, or if domestic commitment to mitigation action facilitates global collective action.

The present section discusses how options to address climate change might be balanced. We focus mostly on the international level decision problem, but do refer to the national level problem as well.

## *Putting the Horse Before the Cart: Deriving the Need for Mitigation from the Inability to Adapt*

Since climate change emerged as a major international issue some 20 years ago, the debate has focused for the most part on mitigation. As a result, the major pieces of international law that currently address climate change—the UN Framework Convention on Climate Change (1992), the Kyoto Protocol (1997) and the EU Emissions Trading Scheme (2003)—all focus primarily on mitigation, recognizing common but differentiated responsibilities.[8]

In this context, the debate over developing countries participation in the future climate regime narrows down to two questions: When will developing countries take on mitigation commitments? And how stringent will these commitments be? Negotiating on this basis has proved very difficult, and the controversy over how and when they should join the mitigation effort is far from resolved to date. Some countries, chief among them the U.S., have consistently argued that large emitters among developing countries should take on commitments rapidly. Most developing countries, on the other hand, have typically been reluctant to even discuss this possibility (Hourcade, 2003), and have called for more attention to adaptation.

The poorest countries emphasized adaptation early on, on the grounds that they would not be able to contribute much to mitigation, but would suffer from the costs of adapting to a changing climate to which they had not contributed (and many would not contribute) significantly.[9] In addition, most developing countries (like many developed countries) were concerned that mitigation would adversely affect economic growth and ability to develop (e.g., Heller and Shukla, 2003). In fact, although the IPCC (2007c) reports relatively modest global costs of mitigation, the range of modeling results is large. The impact on growth, in the case of developed countries, is expected to operate through increased capital and operating costs in emitting sectors (for the same output) and premature retirement of existing capital stock.

In the case of developing countries, the impact on growth is expected to come through higher cost of modernization, if it takes place in the context of expensive rather than cheap energy—thus making it more difficult to close the per capita income gap with industrial countries. Finally, competitiveness issues arise in both developed and developing countries, if individual countries try to take mitigation actions unilaterally outside a collective action framework.

*We argue that there are good reasons to treat adaptation as the primary rather than the secondary concern when addressing the climate change challenge within countries, as well as globally***.** First, as noted above, some countries have essentially very limited mitigation opportunities, but *all* face adaptation needs. Second, in practice, we observe delays in coming to an effective agreement on mitigation, and we expect that these delays will continue. *If globally no (or insufficient) action is being undertaken to mitigate, then implicitly one is behaving as if adaptation were cheaper***.**[10] Third, we are beginning to observe the early impacts of climate change (in part a consequence of delayed action for the past 20 years) and there is already a need for adaptation to deal with these initial stages.

*A response to climate change based solely on reactive adaptation, however, is very unlikely to minimize the total climate bill* for two key reasons. First, even *if it is technically and economically feasible to cope with some impacts of climate change, it is not necessarily cheaper to do so* than to engage in *ex ante* actions (proactive adaptation or mitigation). For example, though it might be technically and economically feasible to evacuate coastal cities, building dikes *ex ante* might prove cheaper, and reducing emissions to limit sea-surges even more so. Much of the reluctance to move more effectively on mitigation is predicated on the assumption that adaptation costs will either be low or occur faraway in the future, when many countries are better off and able to cope with the consequences of climate change (Schelling, 1995). Yet it is unclear whether in fact the costs of adaptation will be lower than the costs of mitigation, and how they will be distributed over space and time, because information on the costs of adaptation is still limited (Adger et al., 2007). *Closing this information gap is a critical challenge facing analysts and modelers.*

Second, and more importantly, *mitigation and adaptation are not perfect substitutes for each other*.

If some losses are irreversible, then proactive adaptation (or reactive adaptation, for that matter) cannot restore them (for example, loss of polar species, glacial ecosystems, or submerged coastal cities). Large *residual* damages remain. Mitigation, on the other hand, can avoid those irreversible losses, provided it is undertaken early enough. In addition, mitigation is the only game in town to avoid potentially catastrophic consequences of climate change (such as a shift in thermohaline circulation).

Thus, the likely inability to fully adapt at low cost requires some degree of mitigation action. On the other hand, *a policy response relying on mitigation only is also very unlikely to minimize the total climate bill*—if only because some future changes in the climate are already locked-in, leaving no option but to adapt to those consequences (see also the following section).

## *Combining Options is Preferable to Picking One: The Case for an Integrated Portofolio of Actions*

The previous discussion thus suggests that *an integrated portfolio of actions that encompass simultaneously some mitigation actions, some proactive adaptation actions, and some reactive adaptation actions will be superior to any individual type of action alone in minimizing the total climate bill.*[11] Working backwards from the ability to adapt to climate change we get the following priorities:

- Where the ultimate damages are likely to be low or inconsequential, the whole problem can be ignored—but we have argued above that this is not likely to be the case globally in the long run (though it could be relevant in the short run for some locations).
- Where ultimate damages are expected to be of a magnitude or a type that one can cope with at low cost, reactive adaptation will dominate. However, even then one has to identify *irreversibilities* that might be incurred, and consciously make a decision that the residual damages associated with these irreversibilities are acceptable.
- Finally, where the ultimate damages associated with climate change will generate vulnerabilities that cannot easily be coped with, or will generate irreversibilities that cannot be accepted, preventive *ex ante* action—proactive adaptation or mitigation—is necessary. The balance between

proactive adaptation and mitigation will depend on the structure of uncertainties and risks, which we discuss in later sections.

Because of the *inertia* in the climate system, there will always be a lag between *ex ante* actions and their effects, so one needs to schedule *ex ante* actions (whether mitigation or proactive adaptation) well in advance. This implies that a portfolio of action is needed *at any given moment in time*. For example, all three types of action to deal with climate change damages are needed simultaneously *now*: some damages are occurring already requiring *reactive adaptation now*, others are unavoidable in the near to medium term, and the cost of coping with them can be reduced with *proactive adaptation now*, while others may occur further in the future and cannot be coped with cost-effectively even with proactive adaptation, thus requiring *mitigation now*. Some *ex ante* actions (such as proactive adaptation) can be taken unilaterally, but others (primarily mitigation) will require collective action.

The balance between actions, however, will need to adapt *over time*. First, because of the time lag between action and consequences, windows of opportunities to avoid or reduce particular categories of damages are closing continuously. In addition, climate change is likely to be non-linear. The speed with which temperature will increase is not known, but the presumption is that it could accelerate in the absence of mitigation action due to positive feebacks between emissions and temperature (e.g., Friedlingstein et al., 2003). We also don't know the extent of additional damages that will accompany *each* supplementary degree above current levels, but again the presumption is that the *damage increment will be larger with each additional degree* (IPCC, 2007b). Thus, minimizing the climate change bill in the presence of uncertainty and non-linearities must be treated within a portfolio of actions that is *capable of adapting. It should be negotiated and planned as such.*

In the discussion above we have tried to clarify, from a practical point of view, why a portfolio of action that combines proactive and reactive adaptation with mitigation is desirable and possibly unavoidable. Next, we propose to show that mitigation and adaptation are so tightly linked that they need to be thought through and addressed jointly and simultaneously. Since the need for adaptation usually depends on the level of mitigation, and since the level of mitigation depends on the ability to adapt, what

should be the balance between the two? Within the adaptation portfolio, what should be the balance between proactive and reactive adaptation? The first question is especially relevant for negotiations at the global level, whereas the second is also relevant at the national level, especially for countries with limited ability to contribute to mitigation.

## *The Interactions Between Mitigation and Adaptation Reinforce the Need for an Integrated Portfolio of Actions*

Building on Kane and Shogren (2000), Lecocq and Shalizi (2007a) analyze the optimal balance between mitigation, proactive adaptation, reactive adaptation, and residual ultimate damages in a partial equilibrium, dynamic optimization model. The analytical resolution of the model confirms many standard results in economic analysis of mitigation policies—notably that the marginal costs of abatement must be equal to the discounted sum of the marginal damages of emissions in all sectors/regions over all future periods. Also, adaptation—whether proactive, reactive, or a combination—in specific sectors, regions, and periods should be financed up to the point where the last dollar spent is matched exactly by the discounted value of the avoided damages (in the *future* for proactive adaptation, vs. *now* for reactive adaptation).

The analytical resolution of the model also confirms that the interactions between mitigation, proactive adaptation, and reactive adaptation determine the optimal levels of these three components in the model (Shibata and Winrich, 1983). If mitigation and adaptation, whether proactive or reactive, are independent, their optimal levels can be determined separately. In particular, the optimal level of adaptation would *not* depend on the success or failure of mitigation policies. So observed delays in implementing mitigation measures would not have any consequences for adaptation actions. If, on the other hand, mitigation and adaptation are *interdependent—i.e., if the marginal benefits of mitigation in terms of avoided damages depend on the level of adaptation*—then the optimal level of mitigation and the optimal level of adaptation cannot be determined independently. Then, a commitment to more adaptation would require less stringent mitigation targets. By the same token observed delays in implementing mitigation measures would require a different amount of (and probably more) proactive adaptation

actions.

In fact, mitigation and adaptation are often interdependent (Klein et al., 2007). First, some activities simultaneously influence both mitigation and adaptation—sometimes reinforcing and sometimes offsetting each other's effects. For example, planting trees can have a cooling effect on surrounding areas by providing additional moisture (adaptation) while removing carbon dioxide from the atmosphere (here adaptation reinforces mitigation). By contrast, developing air conditioning to cope with warming, or desalinization to cope with warming-induced water stress (both adaptation measures) may result in higher energy demand and GHG emissions if electricity is generated by fossil fuels (here adaptation offsets mitigation).

Second, the *efficiency* of adaptation measures often depends on the *level* of mitigation, and vice versa. For example, in the absence of mitigation, sea-level rise in some areas may be such that no seawall can possibly protect the coastline. Neighborhoods and even cities may have to be relocated, at very high cost, with limited possibility for reducing the residual damages because the submerged physical capital is lost. With sufficient mitigation on the other hand, sea-level may not rise as much and seawalls could become effective. It might then be more cost-effective to invest in proactive adaptation in the form of seawalls than to relocate the city. In this example, mitigation and proactive adaptation are complements, but they can also be substitutes. For example, high levels of mitigation that limit temperature increase may allow some threatened ecosystems to survive and thus make it unnecessary to adopt costly proactive protection measures.

Similarly, proactive adaptation and reactive adaptation are often not independent, and their optimal levels cannot be determined separately. For example, modifying zoning plans *ex ante* to account for increased risks of floods reduces the need for costly evacuation and sheltering of victims in response to a flood *ex post* (substitution). On the other hand, investing in advance in upgrading emergency response teams' capabilities (PA), through better training and equipment, will enable them to react more efficiently when a disaster occurs (RA) (complements).

The interdependence between mitigation and adaptation has four implications. First, it reinforces

the importance of improving our knowledge about the costs and benefits of adaptation—*currently underdeveloped relative to mitigation*. Second, it suggests that introducing adaptation into numerical models that assess the costs and benefits of climate policies is very important—*not as an add-on, but as a potentially important factor in shaping mitigation decisions*. Third, from a policy perspective, it suggests that *mitigation policies and adaptation policies should be negotiated jointly and not separately as is essentially the case today at the international level, and that they should be developed and planned jointly at the national level*. Fourth, the interdependence between mitigation and adaptation is an additional argument in favor of an integrated portfolio of actions.

## *Balancing the Portfolio of Actions under Uncertainty*

In frameworks where only mitigation is discussed, the shape of the *aggregate* damage function—i.e., the timing and size of the damage—is the most important uncertainty for setting the optimal level of mitigation (Ambrosi et al., 2003). However, when adaptation is introduced, uncertainty on the *distribution of damages across space/regions* also becomes an issue since the benefits of adaptation are sector- and site-specific.

This has implications for the optimal division of resources between mitigation, proactive adaptation and reactive adaptation. First, the more uncertain the location of an impact, the more cost-effective mitigation becomes relative to proactive adaptation (Lecocq and Shalizi, 2007a). Second, in contrast to the mitigation vs. proactive adaptation balance where uncertainty favors earlier action, in the case of the proactive vs. reactive balance, uncertainty favors reactive adaptation over proactive adaptation—to the extent proactive adaptation and reactive adaptation are substitutes (but not if they are complements). This is because proactive adaptation measures, and particularly those that consist of building or strengthening *fixed, long-lived capital stock*, have a higher chance of being *misdirected* when there is uncertainty on the location of impacts. This uncertainty is resolved once climate change events occur, hence the greater efficiency of reactive adaptation. In other words, with uncertainty on location, the costs of making mistakes—i.e., of adapting in sectors/regions that finally will suffer less than expected—begins to erode

the expected benefits of proactive adaptation. *Mitigation, on the other hand, reduces all damages regardless of the region/sector, and is thus unaffected by uncertainty over the distribution of impacts.* (However, it remains affected by the uncertainty over the timing and magnitude of impacts.)

Lecocq and Shalizi (2007a) draw from this analysis a typology of situations with different implications for the balance of the portfolio of actions under uncertainty:

- If uncertain impacts will occur with high confidence in known locations, then targeted (site-specific) proactive adaptation has the highest chance of remaining cost-effective [12] (even if it involves producing fixed long-lived capital stock), because the risk of misdirecting investment towards the wrong region/sector is low. For example, one might invest in water management infrastructure to reduce tensions on water resources that are likely to emerge in regions already under high water stress.
- If uncertain impacts will occur with high confidence, but whose precise location remains uncertain, then non-targeted (i.e., non site-specific) proactive adaptation measures may still remain cost-effective if they cover enough sectors or regions. Examples of non-targeted proactive adaptation measures include setting up country-wide disaster response and management capabilities, or developing appropriate insurance markets.
- If uncertain impacts will occur with low confidence, and locations remain uncertain, then depending on the scale of the impact, mitigation or reactive adaptation is more likely to be cost-effective relative to proactive adaptation.

## An Integrated Portfolio Makes Sense Even Within a Broader Perspective

The discussion above is framed in a partial equilibrium approach focused primarily on climate change. However, given the magnitude of the problem, and the fact that resources are limited, it is necessary to look at climate change in the broader context of other challenges to development.

## *Views on the Appropriateness of Incorporating Mitigation into Development Strategies from a Broader Perspective*

When looking at the problem from a broader perspective, the idea that early anticipative action (be it mitigation or proactive adaptation) is necessary has been challenged by a number of authors. Three lines of criticism stand out.

The first line of criticism is associated with Thomas Schelling (1995, 2006). He argues that the main beneficiaries of mitigation will be developing countries, since they account for the largest part of the Earth's surface and the greatest proportion of population exposed to climate variability. They are also the most vulnerable—with limited ability to cope, given their current level of development. He further argues that instead of industrialized countries putting a lot of funds into mitigating themselves, or putting pressure on developing countries to mitigate, they would be better off transferring equivalent resources *directly* to developing countries *today*—in order to facilitate more rapid growth in developing countries and increase their ability to cope with climate change consequences when they arrive—, rather than *indirectly* through avoided costs in the *future*. The argument rests on the assumption that future generations will be wealthier and technologically more capable than today's (i.e., there is less need for *inter*-generational transfers), so that there is a premium on helping the poor today (i.e., there is more need for *intra*-generational transfers now). This is an important and valid point, but, as noted above, it is predicated on the assumption that adaptation will be cheap relative to mitigation, which has not yet been demonstrated. In addition, the core weakness of this position is that it *understates potential economic and technical irreversibilities*: Mainly encouraging growth and development in the hope that it will increase adaptation capabilities in the future does not address the fact that adaptation and mitigation are *not* perfect substitutes (see pages 11-12), since adaptation cannot meaningfully and cost-effectively address many types of species extinction, ecological destruction, or other catastrophic risks.

The second line of criticism is associated with the Copenhagen consensus (Lomborg, 2004),[13] which notes that there are many immediate and important risks and challenges facing developing countries

that dominate actions to address climate change. In other words, policies that address many of these other problems have a higher cost-benefit ratio than policies that address climate change. This is also an important and valid argument. But it does not exclude the need for mitigation as even the analysis of climate policies on which the Copenhagen Consensus is based (Yohe et al., 2008) has a positive cost-benefit ratio, despite the fact that it does not fully include uncertainty or catastrophes. In addition, this analysis does not take into account the fact that because of the decade-long lag structures between action and consequences in the climate change arena, earlier actions that avoid bad lock-ins and favor good lock-ins can dominate later actions.

A third line of criticism comes from technological optimists who argue that exogenous technological change will allow us to reduce emissions drastically (see e.g., the lowest-emissions business-as-usual scenarios reported in IPCC, 2007c), or to find a geo-engineering solution to climate change (even if the latter are still recognized to be costly financially). As a result, there is less need for costly anticipative actions now. While there is ample evidence that exogenous technological change is a major driver of growth and development, there is much less certainty that the necessary technologies will *automatically* emerge *in time* to forestall the negative consequences of climate change (i.e., without early changes in incentives and institutions to stimulate research into and diffusion of desired technologies). Since insurance markets cannot address global systemic risk, there is a need for a global insurance policy in the form of actions now on incentives and institutions to stimulate R&D into desired technologies, *and ensure that they are brought on line in time*. Otherwise the World, and particularly developing countries, could be confronted with the need for draconian adjustments and potentially serious social conflict if the necessary technologies do *not* automatically emerge in time. The geo-engineering options also carry the risk of uncertain consequences associated with mega interventions in a web of relations we do not yet fully understand.

A key issue ignored in the lines of criticism above is the role of *learning by doing*—both in terms of speeding up the generation of information that resolves uncertainty, and in terms of speeding up the rate at which the cost of action (e.g., developing viable alternative technologies) is lowered over time. Arrow and

Fischer (1974) and Henry (1974) have noted that in the presence of uncertainty and inertia, increasing information that might resolve uncertainty in the future (at least partially) increases the cost-effectiveness of courses of action that leave options open (i.e., there is an option value to retaining flexibility). Translating this approach to climate change, Ha-Duong et al. (1997) show that risk-averse actions (in their model, more mitigation action now, which can be revised upward or downward as new information on climate change materializes) often dominate risk-neutral approaches. The mitigation actions contemplated here would be separate from, and in addition to actions that generate information to resolve uncertainty (i.e., more research on climate change mechanisms and impacts). Several authors have also argued that in the presence of 'learning by doing' early action can expedite the move along the technology cost curve to lower the cost side of the cost-benefit calculations (e.g., Grubb et al., 2006).

Another fundamental problem not taken into account by the three lines of criticism above is the limited ability of cost-benefit analysis and standard discounting to handle the large uncertainty on catastrophic events with low probability or unpredictable systemic effects. In the presence of "unreackonable risks" (Chomitz 2007), or uncertainty in the Knightian sense (i.e., uncertainty about the extent of uncertainty, as opposed to uncertainty in the form of identifiable and calculable risks), Weitzman (2007) argues that one must act as if the chance of an extreme event is significant. He even argues that this issue can dominate discount rate debates. Such arguments will favor larger investments on mitigation to avoid crossing 'catastrophe generating' thresholds.[14]

To sum up, the three lines of criticism of mitigation action (in both developed and developing countries) raise important and legitimate points. However, they do not address the whole gamut of issues associated with climate change, nor do they use methodologies fully adequate to the nature of the problem. We thus conclude that even when looked at from a broader perspective, mitigation will remain an important component of any integrated portfolio of actions to address climate change—whether in developed or developing countries.

## *Sharing responsibilities: The Role of Adaptation in the Public Sector Response*

Though a portfolio of action between mitigation, proactive adaptation and reactive adaptation might be necessary for society, a question remains as to whether adaptation should be part of the portfolio of *public* actions. Since mitigation reduces all climate-related risks—both known and unknown—everywhere, it is a *global* public good requiring collective action (by all nations at the international level, and by all subnational actors at the national level). By contrast, as already noted above, adaptation reduces specific classes of risks, often in specific locations. Thus, adaptation can be site-specific (e.g., land-use planning), risk-specific (e.g., R&D on heat-tolerant crops), or both (e.g., hardening of infrastructure). As such, adaptation provides a private good (e.g., a more resistant building benefiting its inhabitants only), a club good (e.g., a mutual insurance fund), or a local public good (e.g., a dyke).

Economic theory suggests that such goods should be self-supplied by the individuals, firms or local communities that benefit from them at the subnational level and not by national governments or public agencies. Similarly, from an international point of view, economic theory suggests that adaptation measures that benefit individual countries should be self-financed by the countries themselves and not by the international community.

The rationale for public provision of resources for adaptation at the national or international level is thus less obvious than the rationale for public provision of mitigation. However, public intervention may still be justified, at the national level vis-à-vis subnational level and/or non-public entities, and at the international level vis-à-vis national level and/or global civil society entities, for standard well-known economic reasons such as imperfect information, barriers to collective action (at the subnational level within a country, or at the national level relative to the international community), moral hazard/free rider problems, externalities within and across countries, network/public good aspects of high fixed cost national and international assets, or budget constraints and the ability to pay of the poor (see Lecocq and Shalizi, 2007a for a discussion).

Thus, despite the fact that adaptation yields mostly private or local public benefits, economic theory

suggests that there are many circumstances warranting intervention by national governments (whether in developed or developing countries) with regard to adaptation, and a wide range of instruments that can be used, ranging from indirect actions such as information provision, standard setting to taxes and subsidies, to direct actions such as financing and direct provision of adaptation resources and institutions. There are also multiple ways in which the international community may support adaptation at the country level on top of what individual countries are doing.

Further empirical work is required to determine how much adaptation is required, how much private agents, developing country governments, and the international community can afford, and *whether the existing framework and level of international funds for adaptation is capable of meeting the needs*.[15] However, the cost-benefit criterion applies to government action, as well as private actions. Thus, the government should only support *proactive* adaptation measures to the extent that the benefits to society outweigh the public costs of implementation.

One advantage of anticipative action, including proactive adaptation, is that if properly planned, expenditures can be *spread out* more easily over time, whereas reactive adaptation may require large expenditures in short periods of time. In the words of Chomitz (2007), "smoothly adaptive" expenditure/investment strategies may be preferable to "lumpy" expenditure/investment strategies in the face of "inexorable calamities" when timing uncertainty is taken into consideration.

Relying on *reactive adaptation* runs another risk. Public resources are rarely stable over long periods of time, especially in developing countries. Both sudden and prolonged climatic shocks can erode the country's fiscal base: Thus, the risks of climate impacts and the risks of low availability of public resources are at least partly correlated and must be addressed in advance. Setting up rainy-day funds (Sobel and Holcombe, 1996, Lecocq and Shalizi, 2007a) may be an appropriate solution. Such funds could still be cost-effective even with low returns, so long as the risk of not being able to react adequately is high because of budget constraints. At the global level, the rainy-day fund is a form of self-insurance whose usefulness is highest when contributions cumulate in the medium-term. At the national level, however, resources might be insufficient relative to the size of the impacts. Therefore, financing of

reactive adaptation may have to be split between a national rainy-day fund and transfers from abroad.

However, even when there is uncertainty on the location of damages, the rainy-day fund may complement, but not necessarily replace, proactive adaptation. More research is required to fully determine the conditions under which rainy-day funds are effective, notably taking into account that the uncertainty on when damages might occur, and that proactive adaptation typically reduces damages during more than one period. More empirical research on the returns to these funds and their contingency to institutional structures in developing country contexts is also necessary.

## The Need for a Broad Review of Development Strategies

The emerging risks associated with climate change make it necessary that all actors, public and private, at least *review* their development strategies, policies, and projects. The discussion above provides a qualitative framework for such a review.

This review should be conducted for all investment projects that take place within the country, be they funded by corporations, communities, households, or individuals—not only for investment programs and projects funded by the government. Similarly, the design of long-lasting institutional arrangements may have to be revised to take climate change into account. For example, when water runoffs are expected to diminish, it is all the more important for long-term water rights arrangements to include strong provisions for resolving tensions (Miller et al., 1997).

The review should also encompass all sectors, not just 'climate-sensitive' or 'GHG-emitting' ones. In fact, current *adaptation* literature focuses mostly on a limited number of sectors (notably agriculture) (Adger et al., 2007), and on developing countries (Mendelsohn et al., 2007, Dasgupta et al., 2007). This is understandable given the large share of agriculture in the GDP of many developing countries, and the sensitivity of this sector to the vagaries of the climate. However, because of *growing inter-industry linkages* as development progresses many more sectors will exhibit sensitivity to climate, and attention will have to expand to these other sectors as well—such as various infrastructure sectors (roads for rural markets and global trade, changing the engineering design of infrastructure in areas where glaciers are

disappearing, hardening buildings and infrastructure in coastal areas prone to storms and storm surges, etc.), and emerging alternatives to agriculture, such as tourism. Finally, the indirect effects of climate change on non-climate sensitive sectors, via e.g., factor mobility or markets, may also require that adaptation measures be taken there.

The *mitigation* literature, though much larger, also tends to concentrate on a narrow range of sectors, namely energy supply (volume and mix of fuel). Yet there is a need to *review* development strategies in other sectors as well (Sathaye et al., 2007). For example, demand management policies in energy-intensive sectors can be very effective in reducing the long term trajectory of energy consumption and emissions. In fact, it may be easier to build more compact cities with more balanced multi-modal transport systems (lower inefficient use of energy in transportation), or to build buildings with better insulation and energy efficiency (lower energy demand through better construction), than risk lock-ins and be left with 'retrofitting' long-lasting capital as the only mitigation option. *This is especially important since developing countries are undergoing massive urbanization and will be installing a large part of their long-lived capital stock in the next 15 to 30 years: Addressing mitigation opportunities in these other sectors is critical to avoid potential lock-ins.*

One might object to the need for such a review on the grounds that in many countries, adaptation to *current* climate variability is already part of development strategies. Yet this does not mean that these strategies are also adapted to *future* climate variability associated with climate change. 'Win-win' opportunities in which improving adaptation to current climate variability is aligned with adaptation to future climate variability may well exist (Smit et al., 2000), but careful examination remains warranted. For example, a key development goal for a small, very poor country with a high share of GDP in agriculture might be to improve smallholders' agricultural productivity and their integration into agro-processing. To meet this goal, the high vulnerability of smallholders to currently observed range of weather-related shocks must be reduced through irrigation projects, improved management of key watersheds, and other agriculture development programs that include weather risk mitigation. It would seem at first glance that the country's current development strategy already targets vulnerable rural

communities with the objective of reducing the impacts of weather-related risks. However, these projects and programs may *not* be sufficient to cope with *increased variability* in climate, or with *sustained patterns in climate for which there is no precedent*—such as hundred-year floods or multiyear droughts occurring much more frequently. And they might even be a waste of resources if climate variability increases so much in the future that outmigration[16] of local population and/or shifting the domestic economy towards other, less climate-sensitive sectors becomes the only viable solution.

Finally, though we have focussed on developing countries, it must be clear that the challenge of adapting development strategies to climate change is global. And unlike other challenges, it is new for all countries involved, not just developing ones. Until now, development experts could propose development strategies drawing on the rich experience of industrial countries in transforming their institutions and policies to facilitate industrialization and growth (i.e., going from a low to a high asset base). Developing countries could also benefit from many new technologies to lower the cost of their development relative to what industrial countries incurred at the same stage of development—a learning process facilitated by freer trade and direct transfer of ideas, knowledge, and capital flows. However, climate change adds a new dimension to the problem for which even industrial countries do not always have the necessary institutions, experience, or technology to share. The learning process has now become truly global.

# Conclusions and Recommendations

Improving people's quality of life, and not just standard of living, is a major goal of most societies globally. This involves transforming institutions to manage a broad portfolio of assets: not just physical and human capital, but also social and environmental assets as well as knowledge and technology (World Bank, 2002). Development strategies that transform institutions and policies to move from a low and narrow asset base to a high and broad asset base – to support a higher quality of life – operate within a set of constraints including, *inter alia*, geography, endowments in natural resources, climate, history, culture, and economic environment. Climate change is a new challenge creating headwinds for development.

We have provided a roadmap for assessing the consequences of climate change for development

strategies. We find that *the presence of climate change makes it necessary to at least broadly review development strategies*, regardless of the sources of funding (foreign and/or domestic). Though the mitigation debate focuses primarily on the energy sector, and though the adaptation debate focuses primarily on climate-sensitive sectors such as agriculture, input-output relations in multi-sector models highlight the importance of indirect effects of climate change on the rest of the economy, *hence the importance of reviewing development strategies even in apparently non climate-sensitive and non GHG-emitting sectors*. In particular, it is critical to review projects and programs that involve long-lived, fixed capital stock, and to adjust investment strategies – notably in countries undergoing major urbanization. Similarly, the design of long-lasting institutional arrangements will have to be revised to take climate change risk into account.

Next, we argue that because we face both imminent and long-run impacts, and because the policy responses to climate change risks are interdependent, *there is a need for an integrated portfolio of actions* spanning a spectrum from avoidance of climate change to coping with the damages generated by climate change. In this portfolio, *proactive (ex ante) adaptation is critical*, but also subject to risks of regrets in cases of uncertainty about the location of damages. In particular, *uncertainty on location, favors non site-specific actions* (such as strengthening the ability to react and manage disasters) *or reactive (ex post) adaptation*. Although adaptation often provides private benefits, it should not be left entirely to private agents: *There are strong rationales for public intervention for adaptation both at the national and international levels*—for example when there are spillovers, such as conflicts. To limit the risks that budget constraints might prevent developing countries from financing reactive adaptation—especially since climate shocks often erode the fiscal base—*rainy-day funds may have to be developed* within countries, and at the global level for transfer purposes.

However, *the effectiveness of proactive or reactive adaptation is limited as some losses are technically or economically irreversible*, such as for biodiversity or culturally valued sites and monuments. As a result, *some level of mitigation might be, in many cases, the cheapest option for addressing long-term climate change*. It is also the only option to avoid thresholds that generate truly

catastrophic consequences. In fact, *it is highly unlikely that the effort on any one type of action in the portfolio of action types will be zero in any country over the next few decades.*

Finally *since mitigation and adaptation are interdependent, mitigation policies and adaptation policies should be negotiated jointly at the international level and not separately,* as is essentially the case today, and should be designed and implemented jointly at the national level. Adopting such a package could in turn increase the probability that a global treaty can be devised that fairly addresses the needs and capabilities of the diverse constituencies.

A caveat must be noted here on the methodology used in this analysis. Optimization tools are very powerful conceptually to determine an optimal portfolio of actions. In practice however, it may be very difficult to operationally define such a portfolio without additional information and data. It may even be *irrelevant* in some cases to worry about trade-offs at the margin, if current actions are *sub-optimal* in aggregate, and if one needs to move forward on multiple fronts simultaneously (because we are far inside the production frontier, rather than being on the frontier). Weitzman's criticism (2007) of consumption smoothing cost-benefit analysis in the presence of potential catastrophic events also applies to our framework. However, the key message remains: resources can be misallocated if one just funds activities because they might hypothetically address climate change. Some effort has to be made to construct a portfolio of actions that recognizes tradeoffs and the fact that we face simultaneously different damages with different lag structures between actions and their benefits.

The paper also identifies big gaps in the literature. First, more *disaggregated* information about likely damages—in terms of magnitude, location, and timing—is necessary to get a better quantitative sense of the optimal balance between mitigation, reactive adaptation, proactive adaptation, and residual ultimate damages. In particular, more research is required on path dependency (lock-ins) and poverty traps. But as noted above, there is already a lot of scope for action with the information we currently have. Second, more work is required on *how to separate the costs of adaptation from normal development expenditures*, in order to determine the extra resources required. On that basis, further empirical work is required to determine how much adaptation is required, how much private agents, developing country

governments, and the international community can afford, and *whether the existing framework and level of international funds for adaptation is capable of meeting the needs.* More research is also needed to determine the conditions under which rainy-day funds are effective. Third, introducing adaptation in numerical models that assess the costs and benefits of climate policies is very important—*not as an add-on*, but as a potentially important factor in *shaping mitigation decisions.*

Finally, a priority for future research should be on how to *operationalize* this framework—i.e., determining how development strategies should be modified and what should be the balance of actions in an integrated portfolio of actions—at the country or regional level. This requires in particular further analysis of the relationships between the national and international levels. If, in the presence of uncertainty, mitigation is indeed more cost-effective than adaptation, then one needs to understand how the need for collective action on mitigation can be strengthened at the international negotiation level, including by developing country negotiators. Second, since the extent of mitigation is for the most part exogenous for individual country policy makers, one needs to explore to what extent optimal country-level adaptation strategies depend on this exogenous parameter. We note in conclusion that despite focusing on how climate change affects development strategies, the discussion in this paper shows the centrality of addressing development issues in climate change negotiations as well.

# Endnotes

[1] Large water-stressed inland cities such as Beijing, Delhi, Kabul, Tehran,, etc,

[2] Cheap sea transportation favors export industries in coastal cities. Yet the latter are more vulnerable to climate-change induced sea-level rise, hurricanes, and associated sea surges.

[3] http://www.sante-jeunesse-sports.gouv.fr/IMG//pdf/PNC-2008.pdf, last accessed 15-08-2008.

[4] Lump sum transfers of resources to victims of climate change are not included in RA, because they do not affect the size or efficiency of the economy.

[5] Currently most studies rank competing concentration targets by adding the costs of mitigation and the ultimate damages associated with each target, the former and the latter established independently.

[6] Hydropower potential may increase in northern latitudes as a result of climate change, but may decrease in temperate/Mediterranean regions (Lehner et al., 2005) and in tropical areas such as the Andes (Bradley et al., 2006).

[7] Now estimated to be the largest in the World.

[8] In fact, a Least Developed Countries Fund under the UNFCCC supports, *inter alia*, the preparation of National Adaptation Plans of Actions. The Kyoto Protocol also establishes an Adaptation Fund supported by shares of the proceeds of the sales of Certified Emission Reductions under the Clean Development Mechanism. But overall, resources available for adaptation remains limited (Tompkins and Hultman, 2007). Another reason for focussing on mitigation is the availability of a common metric for most actions. A comparable metric is not yet available to evaluate and compare the efficacy of adaptation actions.

[9] For a history of climate negotiations, see Grubb et al. (1999).

[10] Or cynically as if the costs were to fall conveniently on the weakest members of the society within countries or globally. (Although failure to take action could also be explained by the difficulty of collective action between Sovereign Nations without an external enforcement mechanism.)

[11] Few studies attempt to estimate numerically the optimal balance between mitigation and adaptation. Bosello (2004) and de Bruin et al. (2007) both find that introducing RA in global optimization models significantly reduces the total climate bill, and that the optimal portfolio of actions include both mitigation and adaptation. However, as of Spring 2008, their models include neither PA nor uncertainty.

[12] Callaway (2004) makes a similar point that irreversible investment for adaptation will be undertaken when it becomes clear that the climatic events they are aimed at adapting to are not random, but part of climate change.

[13] See also http://www.copenhagenconsensus.com, last accessed 24-09-2008.

[14] Heal (2008) shows that neither low values for the pure rate of time preference nor catastrophies are necessary to generate the need for high levels of mitigation action early.

[15] Cf. end note n°8.

[16] Historically, outmigration was a natural adaptive response to climate events such as prolonged droughts. However, it often led to conflicts with settled or nomadic populations in the regions to which the eco-refugees moved.

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