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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Climate change is a new and important challenge to development strategies. In light of the current literature a framework for assessing responses to this challenge is provided. The presence of climate change makes it necessary to at least review development strategies—even in apparently nonclimate-sensitive and nonpolluting sectors. There is a need for an integrated portfolio of actions ranging from avoiding emissions (mitigation) to coping with impacts (adaptation) and to consciously accepting residual damages. 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 nonsite-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, on modeling the interrelations between mitigation and adaptation, and on operationalizing the framework. JEL codes: O10, Q54, Q56

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 the land and on 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 headwind.

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”, that is, 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 have contributed little to the current concentrations of GHG in the atmosphere and that they 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”, that is, adaptation.

The present paper addresses the following questions within a framework for assessing responses to the challenge that climate change poses to development strategies. Is it worth revising development strategies for climate change? 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 provide a brief review of the literature on the risks that climate change poses to economic development, and the options available to respond. Second, we argue for an integrated portfolio of actions, including both mitigation of and adaptation to climate change (for both developed and developing countries)—because mitigation and adaptation are not entirely substitutable. We also review the literature on how to balance this portfolio given the uncertainties about climate damages. Third, we discuss why an integrated portfolio remains necessary despite criticisms that mitigation is a low priority for
development and that there is no public sector role in adaptation. Fourth, we argue for a broad review of development strategies. Fifth, we discuss some of the limitations of the current literature on the topic and we identify 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 $\rightarrow$ GHG emissions $\rightarrow$ Atmospheric concentrations of GHG $\rightarrow$
Climate change $\rightarrow$ Impacts on physical and ecological systems $\rightarrow$ Impacts on economies and human welfare

Climate Change Threatens Economic Development

Climate change matters to policymaking only if its potential ultimate damages are expected to be significant, that is only if the expected laissez-faire or business-as-usual scenario with climate change differs markedly from the expected laissez-faire scenario without climate change. A converging set of data and projections suggest that such a significant difference is in fact likely (IPCC 2007a, 2007b). The ultimate damages of climate change arise from both gradual and rapid changes in climatic averages (mean precipitation, temperature, and so on), as well as increases in the variance, frequency, or magnitude of climatic shocks—all of which have 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-1990s estimated these costs at around 1.5–2.0 percent of World GDP in 2100 for temperature increases of 2–3 degrees Celsius by 2100 (see Pearce and others 1996 for a summary). New analysis in the early 2000s found generally lower costs (Mendelsohn and others 2000; Nordhaus and Boyer 2000; Tol 2002a, 2002b). But Stern (2007) has recently reported costs in the range of a 5–20 percent annual equivalent loss of World GDP from now up to 2200. The changing estimates reflect improvements in data and methods over time (for example, the inclusion of risks including catastrophes), evolution of scientific views about certain aspects of climate change (for example, mean temperature increase in 2100 for a given emissions path), and differences in the choice of key parameters (for example, 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 resource availability is already an issue (see, for example, Kundzewicz and others 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 and others 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 (for example, agriculture or tourism), the indirect impacts on nonclimate-sensitive sectors, rigidities in factor allocation and in price adjustments (Hallegatte, Hourcade, and Dumas 2007), and the strength of institutions and the 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 would 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, Krugman, and Venables 1999) can magnify the national or global consequences for economic growth of localized impacts of climate change on key localities (such as major cities that constitute national engines of growth) (Huq and others 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 Response Options: Mitigation, Proactive Adaptation, Reactive Adaptation, and Accepting Residual Damages

To limit the impacts of climate change on economies, countries can mitigate emissions or adapt to climate change consequences. Mitigation 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 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 kilowatt-hour 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 from the atmosphere (that is, 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 following natural disasters are all examples of adaptation actions.

In addition, following Smit and others (2000), two forms of adaptation are distinguished. Reactive adaptation focuses on coping ex post with the adverse impacts of climate change, when they occur. Proactive (or anticipative) adaptation, on the other hand, focuses on lowering the costs of coping ex ante. Proactive adaptation encompasses measures taken in advance to limit the ultimate damages of climate change 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, Smith, and Tol (1998), the distinction between proactive adaptation 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 the historical average, the French government prepared a Heat Wave National Action Plan that includes among other things 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 (that is, reactive adaptation) and in anticipation of future repeat events (that is, proactive adaptation)—as such, it is a typical example of a “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 is very different. Proactive adaptation (like mitigation) uses resources now to prevent possible crises 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. Yet 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—for example, installing early warning systems or fixing...
dikes—are often lower than the costs of deferred action, even when appropriately discounted, thereby making proactive adaptation preferable (Athukorala and Resosudarmo 2005; Burby 2006).

Finally, the term “ultimate damages” is used for damages that would be incurred in the absence of any policies—even if some private adaptation is implemented—and “residual ultimate damages” is used for those damages that remain after all mitigation and adaptation expenditures have been incurred, because they are technically irreversible (for example, lost species) or economically irreversible (that is, reversibility may be feasible technically, but is considered too costly, for example, the full restoration of the Everglades ecosystem or the Aral Sea).

There are thus four main options only for reducing the ultimate damages of climate change: mitigation (ex ante), proactive adaptation (ex ante), reactive adaptation (ex post), and accepting residual damages.

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 or laissez-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 laissez-faire scenario without climate change (S1) no longer describes any real-world situation. The appropriate counterfactual scenario (to determine the real opportunity costs) is now one in which no action whatsoever is taken against climate change and that, as a result, the full set of associated damages are incurred on the whole portfolio of assets (S2).

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 was 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 laissez-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 does not 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
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).\textsuperscript{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 show—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 of the investments could be stranded or wasted, especially if the timeline is compressed due to an acceleration in climate change.\textsuperscript{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 to minimize the global climate bill, that is, to minimize the

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**Figure 1.** Illustrative Growth over Time in the Laissez-faire Cases without Climate Change and with Climate Change; and in Two Policy Scenarios without and with Anticipative Action
sum of the costs of mitigation, proactive adaptation, reactive adaptation, and the acceptance of 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, 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.

In this section we discuss how options to address climate change might be balanced, primarily at the international level, but also with reference to the national level.

**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.

In this context, the debate over the participation of developing countries 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 United States, 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 the ability to develop (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 the 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, there have been 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, the early impacts of climate change are being observed (in part a consequence of the delayed action of 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 will be 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 and others 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, the 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 adapt fully 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.

Combining Options is Preferable to Picking One: The Case for an Integrated Portfolio of Actions

The previous discussion thus suggests that an integrated portfolio of actions that encompasses simultaneously some mitigation actions, some proactive adaptation actions, some reactive adaptation actions, and explicit acceptance of residual damages will be superior to any individual type of action alone in minimizing the total climate bill. Working backwards from the ability to adapt to climate change one gets the following priorities:

- Where the ultimate damages are likely to be low or inconsequential, the whole problem can be ignored—but it has been 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.
- 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 is discussed below).

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 damage is occurring already and requires reactive adaptation now; other damage is unavoidable in the near to medium term. The cost of coping with this damage can be reduced by proactive adaptation now, while other damage may occur further in the future, which 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 nonlinear. The speed with which temperature will increase is not known, but the presumption is that it could accelerate in the absence of mitigation due to positive feedbacks between emissions and temperature (Friedlingstein and others 2003). Also, the extent of additional damages that will accompany each supplementary degree above current levels is uncertain, but again the presumption is that the damage increment will be larger with each additional degree (IPCC 2007b). Thus, minimizing the cost of climate change in the presence of uncertainty and nonlinearities must be treated within a portfolio of actions that is capable of adapting. It should be negotiated and planned as such.

The discussion above has 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. In fact, 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 of the two—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 among 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, then 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—that is 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 and others 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 undermines 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 sea wall 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, the sea level may not rise as much and sea walls would be effective. It might then be more cost-effective to invest in proactive adaptation in the form of sea walls 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 the capabilities of emergency response teams (proactive adaptation), through better training and equipment, will enable them to react more efficiently when a disaster occurs (reactive adaptation)—hence *they complement each other*.

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—that is, the timing and size of the damage—is the most important uncertainty for setting the optimal level of mitigation (Ambrosi and others 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 among mitigation, proactive adaptation, and reactive adaptation. First, the more uncertain the location of an impact, the more cost-effective mitigation becomes relative to proactive adaptation12 (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 that 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 about 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 about location, the costs of making mistakes—that is, of adapting in sectors/regions that finally will suffer less than expected—begin 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 spatial 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 are expected to occur with high confidence in known locations, then targeted (site-specific) proactive adaptation has the highest chance of remaining cost-effective\(^{13}\) (even if it involves producing fixed long-lived capital stock), because the risk of misdirecting investment toward 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 are expected to occur with high confidence, but whose precise location remains uncertain, then nontargeted (nonsite-specific) proactive adaptation measures may still remain cost-effective if they cover enough sectors or regions. Examples of nontargeted proactive adaptation measures include setting up country-wide disaster response and management capabilities, or developing appropriate insurance markets.

- If uncertain impacts are expected to occur with low confidence, and location remains 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 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 those 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 (that is, there is less need for intergenerational transfers), so that there is a premium on helping the poor today (that is, there is more need for intragenerational 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, since adaptation cannot meaningfully and cost-effectively address many types of species extinction, ecological destruction, or other potentially catastrophic events.

The second line of criticism is associated with the Copenhagen Consensus (Lomborg 2004), which notes that there are many immediate and important risks and challenges facing developing countries that dominate the actions for addressing 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 and others 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 for example, 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 is still recognized to be costly financially). As a result, they argue that there is less need for costly anticipative actions now. While this argument is enticing and 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 (that is, without early changes in incentives and institutions to stimulate research into and diffusion of desired technologies). Since insurance markets cannot address systemic global 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 to 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 large-scale interventions on the Earth’s climate in a web of relations not yet fully understood.

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 (for example, 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 (that is, there is an option value to retaining flexibility). Translating this approach to climate change, Ha-Duong, Grubb, and Hourcade (1997) show that risk-averse actions (in their model, more mitigation 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 (that is, 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 (for example, Grubb, Carraro, and Schellnhuber 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 “unreckonable risks”
(Chomitz 2007), or of uncertainty in the sense of Knight (1921) (that is, without ex ante knowledge of the probability of occurrence of the different states of nature). 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.\(^{15}\)

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. Thus, 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 among mitigation, proactive adaptation, reactive adaptation, and accepting residual damages 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 (for example, land-use planning), risk-specific (for example, R&D on heat-tolerant crops), or both (for example, hardening of local and regional infrastructure). As such, adaptation provides a private good (for example, a more resistant building benefiting its inhabitants only), a club good (for example, a mutual insurance fund), or a local public good (for example, a dike).

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 (in relation to the subnational level, nonpublic entities, or both) and at the international level (in relation to the national level, global civil society entities, or both)—for standard well-known economic reasons. These latter include 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 or free rider problems, externalities within and across countries, network or public good aspects of high fixed-cost national and international assets, and budget constraints and the ability of the poor to pay (see Lecocq and Shalizi 2007a for a discussion). There are also a wide range of instruments that can be used, ranging from indirect actions (such as information provision or standard setting) to direct actions (such as taxes on ill-adapted assets or 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. However, the cost–benefit criterion applies to government, 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 more easily be spread out over time, whereas reactive adaptation may require large expenditures in short periods of time. In the words of Chomitz (2007), "smoothly adaptive" expenditure or investment strategies may be preferable to "lumpy" expenditure or 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 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 about the location of damages, the rainy-day fund may complement, but not necessarily replace, proactive adaptation. More research is required to determine fully the conditions under which rainy-day funds are effective, notably, taking into account the uncertainty as to
when damages might occur, and taking into account 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—and 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 run-offs are expected to diminish, it is all the more important for long-term water rights’ arrangements to include strong provisions for resolving tensions (Miller, Rhodes, and MacDonnell 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 and others 2007) and on developing countries (Dasgupta and others 2007; Mendelsohn and others 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 interindustry 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, and so on) and emerging alternatives to agriculture (such as tourism). Finally, the indirect effects of climate change on nonclimate-sensitive sectors, via, for example 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). However, there also is a need to review development strategies in other sectors (Sathaye and others 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 multimodal transport systems (lower inefficient use of energy in transportation) or to construct buildings with better insulation and energy efficiency (lower energy demand through better construction) than to 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 15–30 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 and others 2000), but careful examination is still 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 agroprocessing. To meet this goal, the high vulnerability of smallholders to the 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 many countries’ current development strategies already target 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 climate patterns for which there is no precedent—such as 100-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 outmigration17 of the local population, shifting the domestic economy towards other, less climate-sensitive sectors, or both, become the only viable solution.

Finally, though the discussion has focused on developing countries, it must be clear that the challenge of adapting development strategies to climate change is a global one. And unlike other challenges, it is new for all countries involved, not just developing ones.

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 operate within a set of constraints including, among other things, geography, endowments in natural resources, climate, history, culture, and economic environment. Climate change is a new challenge creating headwinds for development.

This paper has provided a roadmap for assessing the consequences of climate change for development strategies. The presence of climate change makes it necessary to at least broadly review development strategies, regardless of the sources of funding (foreign, domestic, or both). 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 multisector 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 nonclimate-sensitive and nonGHG-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 risks into account.

An argument has been made that because climate change poses 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 explicitly accepting the residual 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 as to location favors either nonsite-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 is a strong rationale 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 also 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 for avoiding thresholds that generate truly catastrophic
consequences. In fact, it is highly unlikely that the amount of effort on any one type of action in the portfolio will be zero in any country over the next few decades. However, the balance between the different components of the portfolio is likely to evolve over time. It should be negotiated and planned as such.

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 they 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 for conceptually determining an optimal portfolio of actions. In practice, however, it may be very difficult operationally to 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 suboptimal in aggregate, and if one needs to move forward on multiple fronts simultaneously (because one is 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 trade-offs and the fact that one faces simultaneously different damages with different lag structures between actions and their benefits.

The paper has also identified 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 among 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 currently available. Second, 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. Third, further empirical work is needed 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. Fourth, more work is required on whether the costs of adaptation can meaningfully be separated from normal development expenditures, in order to determine the extra resources required. Finally, more research is needed to determine the conditions under which rainy-day funds are effective.
Finally, a priority for future research should be on how to operationalize this framework—that is, 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 policymakers, one needs to explore to what extent optimal country-level adaptation strategies depend on this exogenous parameter. In conclusion, on the one hand, the first part of the paper argues that development strategies will in fact look different in the presence of climate change than in its absence, because of the need to incorporate a portfolio of actions to minimize the climate bill. On the other hand, the second part of the paper argues that climate change negotiations are less likely to succeed if they do not explicitly address development issues and the need for an integrated portfolio of actions.

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Notes

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1. Large water-stressed inland cities such as Beijing, Delhi, Kabul, and Tehran.
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.
4. Lump sum transfers of resources to victims of climate change are not included in reactive adaptation, 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 being established independently.
6. Hydropower potential may increase in northern latitudes as a result of climate change, but may decrease in temperate/Mediterranean regions (Lehner, Czisch, and Vassolo 2005) and in tropical areas such as the Andes (Bradley and others 2006).
7. Now estimated to be the largest in the world.

8. In fact, a Least Developed Countries Fund under the UNFCCC supports, among other things, 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 remain limited (Tompkins and Hultman 2007). Another reason for focusing 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.


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; see also endnote 19.)

11. Few studies attempt to estimate numerically the optimal balance between mitigation and adaptation. Bosello (2004) and de Bruin, Dellink and Tol (2007) both find that introducing reactive adaptation 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 2009, their models include neither proactive adaptation nor uncertainty.

12. Even here, there is a caveat. The uncertainty associated with mitigation investments, for example, in hydropower or wind farms increases once climate change is already underway, because past patterns and locations of water or wind flows are no longer reliable.

13. 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.


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


17. 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.

18. Politically, there is an imperative to separate mitigation, adaptation, and development finance. But this raises complex analytic problems. In light of the argument made earlier in this paper, “normal” development in the absence of climate change can no longer be meaningfully defined, because the pattern of development expenditures going forward will already be different (resulting in a higher or lower level of expenditures) in the presence of climate change in order to handle a continuous and changing set of adaptation needs brought about by climate change.

19. Large inequalities lead to a large divergence of interests, which in turn undermine the ability to resolve collective action problems (World Bank 2002). This is why climate change negotiations will not generate robust solutions until development issues are resolved.

References


