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Climate Change:

A Research Agenda for Latin America and the Caribbean

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Abstract[*]

The objective of this research agenda is to outline the issues that need to be investigated in order to produce an informed assessment of what strategies and policies Latin America and its international organizations should pursue with respect to climate change. This report makes the three following potential contributions: i) identifying actions that could be valuable but have not been highlighted; ii) advising on actions that could be ineffective and costly, given limited resources; and iii) recommending an evaluation of what elements require further analysis before objectives are translated into action. After introducing the issues involved, the report presents a simplified model to help explain the interaction of climate change with the economy. The discussion then turns to several of the most important relevant issues in terms of the model. Finally, individual items are discussed in order to construct an agenda.

JEL classifications: Q54
Keywords: Climate change, Mitigation, Adaptation, Latin America and the Caribbean

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Executive Summary

Objectives and Main Conclusions

The objective of this research agenda is to outline the issues that need to be investigated in order to produce an informed assessment of what strategies and policies Latin America and the Caribbean and its international organizations should pursue with respect to climate change.

This agenda was undertaken with the support of the Research Department of the Inter-American Development Bank (IDB), and it benefited from the input of several groups and individuals at the IDB. In particular, we want to acknowledge useful inputs from the Sustainable Energy and Climate Change Initiative (SECCI) team and the investigators of the Research Department and the Integration Department, respectively, as well as comments and suggestions from Federico Basañes, Juan Pablo Bonilla, Eduardo Fernández-Arias, Paolo Giordano, Santiago Levy, Eduardo Lora, Sebastián Miller, and David Wilk.

We believe this report makes three potential contributions:

- Identifying actions that could be valuable but have not been highlighted.
- Warning of actions that could be ineffective and costly, given limited resources.
- Indicating areas that need further analysis before objectives can be translated into effective action.

In regard to interventions, our main conclusions are the following:

- International incentives (in the form of rewards and potential penalties) are biased in favor of mitigation. Rewards include access to financial aid and technology transfer, and potential penalties include carbon taxes on exports and transportation. In the future, it might be that penalties would include trade restrictions.
- Much less has been done in the field of **adaptation** at the international level. Much smaller funds are available and alternative actions have not been ranked according to their cost and effectiveness.

- While LAC countries have not significantly contributed to emissions, they have the ability to contribute to mitigation in relatively efficient ways.
- LAC must be prepared to take advantage of available incentives and develop a consistent strategy of action and negotiation with respect to **mitigation**.
- LAC countries can nonetheless suffer from climate shocks in terms of production and standard of living. Consequently, adaptation becomes a key strategy for LAC.

In regard to future work, on the basis of the discussion in the paper we recommend the following agenda, which consists of two sets of analytical areas that follow from our analysis.

The **Operational Agenda** encompasses analytical questions and issues that can have immediate operational consequences within the IDB. In the typology used by the Bank, this agenda belongs to the categories "Policy and Capacity Development (PCD)" and "Advisory Services (AS)" but in this paper we do not make a distinction between them.

Under the heading of **Research and Development Agenda** (which is also a category in the Bank's typology) we include issues that are relevant but require further study before they can have operational implications.

Operational Agenda

- **Guidelines for mitigation and adaptation project evaluation.** Several operational sectors have shown interest in acquiring a toolkit to complement technical environmental studies with sound economic principles for project evaluation. Among these sectors are transportation and logistics. Research should help to develop this toolkit with specific applications for work to be conducted by IDB staff.
- **Identification of cost-effective adaptation actions.** Though we have identified adaptation as a key element of LAC's strategy for coping with climate change, this area has received little attention, and there is not yet a comprehensive survey of possible actions. Analysis should therefore identify

the most cost-effective actions considering risk,[1] cost and social value. Resulting papers should be useful as a guide for the planning of interventions in LAC, including those to be promoted by the IDB.

- **Financial fragmentation and role of multilateral institutions.** At least 20 funds for climate change—frequently associated with mitigation actions—have been identified, each with its own rules and governance. Overlapping efforts might imply excessive competition for some sources of funds, and lack of access to others. Research should summarize available funds' characteristics and operating rules, and identify how the IDB can coordinate LAC efforts to make access easier and more effective.
- **Sustainable and efficient mechanisms of insurance.** Research in this area should identify supplementary actions that the IDB could undertake to complete the actions of governments and markets. Left alone, markets and even national governments may find themselves unable to provide sufficient levels of insurance. Since regional institutions have a role to play in pooling resources to face an indivisible risk, research should investigate the possibilities of developing a regional system under conditions of voluntary participation and compatibility of incentives.
- **Evaluation of trade and climate change using simulation models.** At present, several models that include climate change as an external shock to the economies are characterized by an abundance of results and methodologies, but that has not been accompanied by gains in transparency for policy analysis and decision-making. Research should survey the most important current contributions, helping us to understand their main assumptions and the quality of data used. It should also make a contribution to the development of an independent transparent model that the IDB can use to simulate sectoral analysis (such as the impact of international prices on agricultural production in LAC) and also to estimate general equilibrium effects (like those stemming from international prices of commodities, and mobility of factors).

[1] The identification of risk will necessitate the elaboration of a technical paper examining in details the major impacts from climate change at relatively fine regional scales, with consideration of local topography, ecosystems, and current climate.

- **Certification and labeling.** There is a need to develop credible environmental labeling for LAC products, and do so at a low cost, in order to confront potential opportunistic evaluations used as trade barriers and to simplify access to markets abroad. It seems recommendable to assist the region in developing that instrument, whether it takes the form of a regional institution or some other arrangement. Research should seek to analyze the methodology and finance of the process.

Research and Development Agenda

- **Dynamics of growth and climate change: The LAC case.** The evaluation of the impact of climate change actions on growth has to be conducted in a macroeconomic integral model. Research in this area should seek to create a common platform for discussing how climate change policies and shocks can affect growth. Also, the dynamics of growth of LAC could change the relative relevance of mitigation vs. adaptation investments. For instance, in the future LAC could play a more important role in total emissions if its rate of emissions growth exceeds that of the rest of the world. The resulting model should permit calibration with different types of LAC economies and simulations of the interaction with other social and economic policies. The study should further include the assessment of several anticipatory scenarios to guide general policies, and do so in line with the lessons and parameters of this research agenda. The resulting model and research should be transferred to the IDB as part of its permanent research assets.
- **Labor market issues.** Two broad issues appear important in this area. One is the question of migrations. Historically, populations have sometimes migrated to cope with changing conditions. Although a population's mobility can reduce the costs of climate change, there may also be undesirable side effects. For instance, populations may move to risk-prone urban areas simply because property prices there are reduced by shocks? The determinants of mobility need to be investigated analytically and empirically investigated, perhaps using historical as well as contemporary evidence. Of key importance is the

role of information and subsidies in enhancing government's ability to help people cope with climate change by relocating to less affected areas.

The other question is how to implement taxes and environmental regulations in an economy where a large fraction of the population is informal. This would similarly require a study that combines an analytical model with empirical evidence; that study should not only be able to predict the effects of different ways to regulate the environment, but also to identify the most efficient course of action. In both cases, the studies undertaken should go beyond understanding the behavior of firms and markets. In particular, they should be designed in a way that facilitates a ranking of possible government interventions.

- **Regional trade agreements.** International community incentives, as well as the different endowments of countries, could create gains for countries that draw independently on special funds, some associated with transfer of technologies. The compatibility of those actions with RTAs is still in doubt and may require deeper analysis so as not to jeopardize trade relationships. Research in this area should contribute to establishing an initial platform for efficient discussion between partners of the main regional trade agreements.
- **Economic impact on LAC of new trade rules.** It is still not clear whether LAC should make an effort to modify its production processes and transportation costs, vis-à-vis the eventual sanctions, in the form of lower prices. The first action leaves rents and income within the Region; the second exports those rents to the rest of the world. The answer can be different depending on the comparative advantages of each country and on the pattern of specialization. The paper should make an assessment using some common and transparent platform of analysis, such as a computable general equilibrium (CGE) model with a basic structure, to assess impacts and policies and to make results comparable, and therefore to guide IDB policies.
- **Trade regulations.** Research in this area should address several issues of concern related to LAC exports and trade. Two are particularly salient: i) how to develop an independent labeling or certification for exports to prevent other

countries from engaging in opportunistic behavior and ii) the harmonization of technology transfer agreements with WTO rules.

- **Sustainable cities**. The boundary of emission accounting in the case of cities is under discussion. One can consider that it is not cities that produce GHGs, but particular activities located there, such as manufacturing industries or power stations. Cities in low and middle-income economies, such as LAC countries, have a lower impact on global warming but will probably face higher risks from the impacts of climate change. Moreover, low-income populations, generally concentrated in risk-prone areas of cities, will be the most affected due to extreme weather events. Research should therefore go beyond mitigation to address investment in infrastructure for adaptation. Particularly important adaptation issues include the following: impact on cities of floods, salinization of water sources, diffusion of diseases in urban areas and how to deal with extreme cases of the urban heat island effect. Though mitigation is a lower priority for LAC cities, ample opportunities may arise to use resources available for mitigation investments in ways that improve urban quality of life in areas such as transportation, among others. Research in this area should provide specific recommendations.
- **Forestry.** Research should focus on opportunities for LAC to prevent deforestation and foster reforestation, identify successful experiences of sustainable economic exploitation and make recommendations on how to include local communities in those opportunities to make programs effective**.** Research should identify opportunities for obtaining resources from funds in ways that minimize LAC countries' search costs, and should assess LAC's possible gains in terms of carbon credits. Research should take advantage of experiences to date and derive relevant lessons.
- **Agriculture.** Research should focus on identifying what policies could be followed to adapt agricultural production to potential climate change shocks, including erosion, floods, wildfires and new diseases, and to establish in which cases IDB action is either advisable or redundant. In the latter regard, the private sector may already be taking the initiative spontaneously in areas

such as developing new crop varieties. Research should help to assess the costs and benefits of policies and to identify efficient ways to diffuse techniques already available, as well as identify research opportunities with significant sectoral impact. Research in this area, as in forestry, should take advantage of experiences and draw lessons for LAC countries.

- **Adaptation Interventions.** Study what should be the priorities for interventions in this area, emphasizing cost-effectiveness and cost-benefit analysis, and taking into account the current uncertainty about the effects of climate changes and the possible complementarities of these interventions with the anti-poverty agenda of the IDB.

Extended Summary

- Even though there is scientific debate about the role of human responsibility in the Earth's recent observed warming, there is some agreement that this is very likely to continue in this century, and that this warming can pose a serious threat to the planet's biosphere, including human life.
- Moreover, the complexity of the climate makes any precise prediction of the relationship between specific concentrations of greenhouse gases and changes in global temperatures extremely difficult. Therefore, we are condemned to live with uncertainty, but this uncertainty means that we should worry more, not less, because while things may not be as bad as the most likely accepted scenarios suggest, outcomes could also be worse.
- We also face uncertainty about the path of future emissions, the cost of reducing them and about the precise effects of climate change.
- The most basic question in choosing a response to climate change is how to act responsibly under uncertainty. Indeed, uncertainty pervades every part of the problem. Given this situation, the international community has chosen a strategy of minimum regret with cost-effectiveness.
- Mitigation and adaptation are the two basic elements of the strategy to deal with climate change. Mitigation encompasses all actions that contribute to reducing greenhouse gases emissions or increasing their capture from the atmosphere and thereby reduce the probability of negative future shocks due to climate change. Adaptation refers to actions to anticipate and/or compensate for the shocks of climate change.
- Conceptually, at least, small countries or regions will tend naturally to rank adaptation over mitigation actions. The reason is clear: there are direct own gains from insurance and compensation, while mitigation does not have any direct discernible effect on the likelihood of future events. Therefore, it is plausible to think that mitigation actions will be developed only as a response

to concrete economic incentives or political pressure from developed countries in their attempt to pursue a global mitigation agenda.[2]

- Given the prevailing uncertainty about all aspects of climate change, there is an option value of waiting to engage in adaptation expenses.[3] The possibility of learning means that a positive value will be attributed to flexibility.
- The temptation to postpone investments, however, can be costly for two reasons: i) irreversibility and regret and ii) high marginal costs of correction of adaptation investments to real needs.
- International incentives (in the form of rewards and potential penalties) are biased in favor of mitigation. Rewards include access to financial aid and technology transfer, and potential penalties might include carbon taxes on exports and their transportation. While not likely in the near future, incentives may eventually encompass broad penalties through restrictions on trade.
- Much less has been done in the field of adaptation at the international level. Much smaller funds are available, and alternative actions have not been ranked according to their cost and effectiveness.
- While LAC countries have not significantly contributed to emissions, they have the capability to contribute to mitigation in relatively inexpensive ways. Preservation of forests and improved agricultural practices are two of the main examples.[4]
- Their historically small share of emissions notwithstanding, LAC countries can suffer from climate shocks in terms of production and standard of living. Consequently, even after taking advantage of opportunities of available resources for mitigation, adaptation is a key strategy for LAC.

[2] Note that even though most LAC developing countries in isolation might not contribute much to global emissions of greenhouse gases, LAC as a whole can contribute to a global mitigation agenda. Note, of course, that all countries, even large emitters, have incentives to free ride others in terms of mitigation.
[3] Conceptually, this is also true for mitigation, though time seems more pressing in this case.
[4] Of course, forestation could even be expanded if this were optimal, given the structure of incentives.

- Over time, however, if LAC's emissions grow in relation to the developed world, and if the Region becomes relatively richer, mitigation may need to play a larger role in its climate change strategy.
- Adaptation includes several dimensions such as access to water, protection against human and agricultural diseases, necessary assistance to the poor, and the development of infrastructure and cities.
- Some adaptation actions can be immediate and inexpensive, such as early alert systems or new regulations for buildings and infrastructure. Others could be costly and can be postponed until more information becomes available. Research and development focusing on the Region's needs can represent a cost-effective way of learning.
- There do not yet exist well-developed guidelines, based on sound economic principles, for the evaluation of alternative adaptation actions. Such guidelines could serve to rank projects under scarcity of resources.
- As in the areas of improving education or reducing poverty, there is ample scope for experimentation and program evaluation in climate change adaptation.
- Guidelines could also prove helpful in the evaluation of mitigation projects. In principle, mitigation projects in LAC should be approved when their net contribution to the economy is positive. In fact, however, practitioners might be prone to accept projects simply because they are expected to contribute positively to reduce global warming or because they are timely and consistently presented, or to take advantage of some available source of funds.
- The basic elements for the evaluation of both mitigation and adaptation projects can be obtained from a simple analytic model. In both cases, the marginal cost of public funds and the opportunity cost of resources are important.
- More specifically, in the case of mitigation there are two parameters that play a critical role: i) the amount of funds from the international community, as well as its elasticity to domestic mitigation efforts, and ii) penalties to export revenues (in the form of lower net prices to exports due, for example, to

carbon taxes on transportation).This implies that the choice for LAC countries could be to accept the transfer of rents to the rest of the world in the form of lower prices for its exports, or to undertake mitigation investments and try to keep some of the profits.

- The critical elements of adaptation are: i) the economic gains of protecting infrastructure, productive capital and health and quality of life, ii) the marginal cost of acting too late versus the immediate gains of postponing expenses, and iii) the acceleration of the growth rate, since relatively high growth could reduce the burden of expenses in future periods and then favor a delay in investments.
- Unfortunately, the information available so far shows ambiguities and inaccuracies in determining the costs of alternative actions can therefore be misleading. Expenses are not necessarily economic costs.
- Fragmentation of financial sources is a key issue as well. It creates overlapping of efforts and a loss of control and efficiency. Multilateral financial institutions can help to reduce transaction costs and excessive competition, as well as to rank projects properly.
- Finally, since there is still much to learn about climate change, this exercise should be refined and repeated over time in order to take stock of new knowledge and to redefine priorities for both research and action.

1. Introduction

In many ways the problem of human-induced climate change is unique: it is global, it will affect the planet for decades to centuries, and it is complex, imperfectly understood, and has the potential for serious consequences.

Perhaps not surprisingly, climate change is also the most contentious environmental issue that we have yet seen, since it which is. When policy issues have high stakes, it is typical for policy debates to be contentious. Because the potential risks of climate change are serious, and the fossil fuels that contribute to it are so important to the world economy, it is not surprising to hear strong opposing views over what to do about climate change (Dessler and Parson, 2010).

At the heart of the climate change debate are two undisputed facts. The first is that certain gases in the atmosphere are transparent to ultraviolet light but absorb infrared radiation. The most important of these gases, known as greenhouse gases, are carbon dioxide, water vapor, methane, nitrous oxide, and chlorofluorocarbons. Energy from the sun, in the form of ultraviolet light, passes through greenhouse gases unimpeded and is absorbed by objects on the ground. As the objects become warm, they release the energy as infrared radiation. If the atmosphere held no greenhouse gases, most of the infrared energy would escape back into space.

The second undisputed fact is that greenhouse gases have been increasing in the atmosphere for the last two centuries or so, primarily as a result of human activity. As noted above, there are strong theoretical reasons, rooted in basic physics, to expect this increase to warm the Earth's surface.[5] A concentration of 400 parts per million (ppm) of carbon dioxide equivalent (CO_2e) will soon be reached (the pre-Industrial Revolution level was around 280 ppm). In fact, a concentration of 750 ppm by the end of the century is predicted on a business-as-usual scenario (IPCC, 2007a).

Beyond these two points, controversy arises. Although greenhouse gases can trap energy and make the atmosphere warmer, and the concentration of those gases has been increasing, it is far from clear what those facts mean for global temperatures. A long list of scientific uncertainties makes it difficult to say precisely how much warming will result from a given

[5] The basic climate physics is uncontroversial among scientists. And if one could change the concentration of a single greenhouse gas while holding the rest of system (except its temperature) fixed, it would be simple to calculate the corresponding change in surface temperature. Almost all the controversy arises from the fact that in reality, changing any single greenhouse gas will indirectly cause other components of the system to change as well, thus yielding additional changes. These knock-on effects are known as feedbacks, and the most important and uncertain of these involves water (Emanuel, 2007).

increase in greenhouse gas concentrations, when such warming will occur or how it will affect different regions and ecosystems.

To address these uncertainties, the United Nations and the World Meteorological Organization established an international body to assess the scientific knowledge on climate change: the Intergovernmental Panel on Climate Change (IPCC).[6] In its last assessment, the IPCC states: "Warming of the Climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPPC, 2007a). In fact, since 1900 the globally surface air temperature, determined from measurements at many meteorological stations, has increased about 0.8^{o}C, with more than half of this increase occurring since 1970 (IPCC, 2007a).[7]

In spite of these figures, it is quite hard to establish how much warming has taken place already. Normal variations in global temperatures are large, and it is very difficult to tell whether actual increases in temperature are outside the usual range and thus determine how much warming has occurred.

Moreover, establishing that human activities are responsible for the recent observed warming is even harder than showing that the Earth is warming, because establishing a *cause-and-effect* relationship requires a causal inference rather than the mere identification of a trend.

While emissions from human activities are a potential cause of recent warming, at least five natural processes are also known to have significant effects on climate: tectonic processes, variation in the Earth's orbit, volcanic eruptions, variation in the energy output of the Sun, and internal variability of climate system. Indeed, the Earth has experienced large climate fluctuations throughout its history, but it is only over the past two centuries that human activities have expanded to the point where they have the potential to influence global-scale processes, including climate.

[6] The IPCC involves hundreds of scientists organized into three working groups addressing the following areas: the atmospheric science of climate change; the potential impacts of climate change and ways to adapt to the changes; and the potential to reduce the greenhouse-gas emissions that the IPPC has identified as the main cause behind global warming. The working groups are further divided into teams who survey the peer-reviewed and published scientific literature and summarize the results.

[7] However, our planet has undergone many different climate changes. Indeed, in the last hundred million years the Earth has been both far warmer and far cooler than today. However, the last few decades of the twentieth century appear to have been warmer than any comparable period over the last 400 years, and possible even warmer than the peak of the medieval warm period, around 1,000 years ago (IPCC, 2007a).

Projecting future emissions introduces further complications, since it involves predicting societal trends rather than conducting atmospheric science per se. Future emissions depend on world population and economic growth, and on technological trends that determine the efficiency of energy use and the mix of carbon-emitting and non-emitting energy sources in use. Consequently, the approach taken by the IPCC is to produce a set of emissions scenarios in which each scenario provides an alternative and internally consistent picture of how world development might shape future emissions trends. Projected emissions in these scenarios span a wide range, from as high as 30 billion tons to as low as 5 billion in 2100. This wide range reflects combined uncertainties about population, economic growth, and technological trends. Considering all emissions scenarios, and taken into account uncertainty in both emissions and climate-system response, projected twenty-first century warming ranges from 1.1^{o}C to 6.4^{o}C (IPCC, 2001).[8] Thus, while there is a wide range of uncertainty in the magnitude of the warming, warming is projected to continue through the twenty-first century by all models under all emissions scenarios.

The risk of climate change depends not just on what happens to the climate system but also on the physical and socioeconomic implications of a changing climate. This adds uncertainty to the problem. Unknown physical risks are compounded by uncertain socioeconomic consequences.

Human settlements, along with their ecosystems and pests, have generally adapted to the climates and geophysical features they have grown up with. It is suggested that those parts of the economy that are insulated from climate, such as air-conditioned houses and most manufacturing operations, will be little affected directly by climatic change during the next century. However, those human and natural systems that are unmanaged, such as rain-fed agriculture, seasonal snowpacks and river runoffs, and most natural ecosystems, may be significantly affected.

Although economic studies in this area are subject to large uncertainties, the best estimate in the impressive work of Nordhaus (2008), is that the economic damages from climate change with no interventions will be on the order of 2.5 percent of world output per year by the end of the twenty-first century. Additionally, the damages are likely to be concentrated in low-income and tropical regions such as tropical Africa and India. Although some countries might benefit from climate change, there is likely to be significant disruption in any area that is closely tied to

[8] See also Below and Persson (2008).

climate-sensitive physical systems, whether through rivers, ports, hurricanes, monsoons, permafrost, diseases, frosts, or droughts (Nordhaus, 2008).

Finally, the cost of reducing greenhouse gas emissions is also uncertain. Thus, in short, uncertainty is the single most important attribute of climate change as a policy problem. Indeed, from climatology to economics, the uncertainties in climate change are pervasive, large in magnitude and very difficult to resolve.

Therefore, the most basic question in choosing a response to climate change is how to act responsibly under uncertainty. Indeed, uncertainty pervades every part of the problem. As is frequently the case, we are faced with the task of rationally deciding the most sensible policy course to take against a background of fundamental uncertainty. We need to avoid being paralyzed into complete inactivity. But we also need to avoid being panicked into what could be disastrously damaging action.

Additionally, in the developing world, including Latin America, other issues, such as hunger, poverty and disease are more pressing than global warming. Certainly, by addressing them, one can help more people at lower cost and with a much higher chance of success than by pursuing drastic climate policies at a cost of trillions of dollars.

Thus, the objective of this research agenda is to outline the issues that need to be investigated in order to produce an informed assessment of what strategies and policies Latin America and its international organizations should pursue with respect to global warming.

We see three potential contributions of this report:

- Identify actions that could be valuable, but have not been highlighted.
- Advise on actions that could be ineffective and costly, given limited resources.
- Before translating objectives into effective action, recommend an evaluation of what elements require a deeper analysis.

The objective of these pages is to contribute to identify those elements and to help identify issues that require further investigation before solutions and policies are put in practice. We shall start by presenting a very simplified model to help explain the interaction of climate change with the economy. We believe that evaluation is facilitated by putting shocks and policies in an economic framework that allows comparison of points of view, identification of

interactions and a better understanding of the costs of "solutions" in terms of income distribution and macroeconomic performance. This framework will also help to determine the true cost of actions and policies for economies; direct expenses are not necessarily economic costs. Second, we shall discuss some of the most important issues in terms of the elements of the model. Finally, we shall take individual items and elaborate on them in order to construct the agenda.

2. Global Warming

As shown by British physicist John Tyndall in the nineteenth century, some gases in the atmosphere act like "blankets" that prevent heat at the Earth's surface from escaping directly into space. These greenhouse gases include carbon dioxide (CO_2) as well as many other gases, both natural and human-made. By far the most abundant greenhouse gas is water vapor. Though these gases allow the Sun's energy to reach the Earth's surface in the form of visible light, they inhibit the escape of heat into space. Indeed, in the absence of greenhouse gases in the atmosphere, the Earth would be on average a chilly -18^{o}C. Greenhouse gases absorbing and emitting radiation keep heat energy in the Earth's lower atmosphere for a longer period before it ultimately escapes to space, warming the surface to a far more comfortable 15^{o}C on average. This is the greenhouse effect.

The industrial era is marked by clear signs of human activity changing the composition of the atmosphere. Indeed, over a century ago, the Swedish chemist Arrhenius had theorized that industrial emissions of CO_2 would lead to increasing levels in the atmosphere and might increase global temperatures. As of 2008, CO_2 is present in the atmosphere at a level of about 384 parts per million (ppm) of air. This may not sound like much, but it is more than 36 percent greater than the 280 ppm concentration at the dawn of the industrial era. Other greenhouse gases also have risen substantially in the industrial era (IPPC, 2007a).

We can view increases in greenhouse gases as a thickening of the blanket that keeps the Earth's surface warm. Anything that changes the energy balance in the atmosphere can be characterized by how much it changes the radiation flux at the top of the atmosphere. Greenhouse gases are a positive forcing, as they prevent longwave energy from escaping into space, implying that more energy is coming in from the Sun than is going out.

Consider now the following thought experiment. Start with the Earth in energy balance and then increase its radiative forcing by doubling the amount of CO_2 in the atmosphere

indefinitely. Now more energy is coming than is leaving, warming the planet. Eventually the atmosphere and ocean will come into a new balance at a higher temperature. Global climate models warm about 3°C with doubling of CO_2, with a range of about plus or minus 1°C. However, the Earth climate system is not a laboratory in which controlled experiments can be performed. Only in a computer model can one increase the CO_2 by a fixed amount, holding all other climate variables constant, and observe the isolated effect on air temperature. In reality, many radioactive forces are changing simultaneously and their effects on climate interact (Archer, 2007). Thus, the complexity of the climate makes any precise prediction of the relationship between specific concentrations of greenhouse gases and changes in global temperatures extremely difficult.

Past climate record shows many examples of temperature fluctuations associated with changes in CO_2. However, the source of variability of CO_2 is not yet well understood. Importantly, in recent times, emissions from fossil fuels can be observed going into the atmosphere, and the atmospheric increase matches the fossil-fuel source in quantity, isotopic mix, and timing (IPCC, 2007a).

Climate scientists give much weight to the result of simulating the climate of the last 100 years with climate models.[9,10] A robust result they find is the following: When the model includes the known natural forces but no human impact on climate, the model reproduces many of the bumps and wiggles in the climate record. But this simulation fails to capture the rapid warming beginning around 1970. Instead, when the model also includes greenhouse gas emissions (as well as sulfate aerosols and stratospheric ozone depletion), the model fits the data better up to 2000 (IPCC, 2007a), though these models have had problems fitting the data in the last decade.[11]

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[9] Of course, computer modeling of global climate is a complex endeavor. A typical model consists of millions of lines of computer instructions designed to simulate an enormous range of physical phenomena. Although the equations representing the physical and chemical processes in the climate system are well known, they cannot be solved exactly. Thus, important effects are parameterized. Indeed, changing the values of the parameters or the way the various processes are parameterized can change not only the climate simulated by the model, but the sensitivity of the model's climate to greenhouse-gas increases (Emanuel, 2007).

[10] Unfortunately, there are only few simple external checks of these models, and hence, projections of future climates must necessarily involve quite a bit of faith (Emanuel, 2007).

[11] Considering the natural forces mentioned above, orbital variations and tectonic processes are eliminated as significant contributors because they are too slow to have any discernible effect on climate over periods as short as a century. Two other processes, volcanic eruptions and changes in solar output, are rejected because we have good measurements of them over the relevant period and they have not shown the pattern of changes that would be required to account for the recent warming. Finally, though internal variability of the climate cannot be ruled out as

Considering all this evidence, in its 2007 report the IPCC concluded "Most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."[12]

As discussed in the introduction, even though there is great uncertainty, all projections based on climate models suggest that the Earth will continue to warm during the twenty-first century. How bad this might be?

Again, uncertainty prevails. One thing, however, is clear: the costs of any global warming that occurs can be reduced by human adaptation. Indeed, the most serious flaw in the IPCC's analysis of the likely impact of global warming is its grudging and inadequate treatment of adaptation, which leads to a systematic exaggeration of the anticipated costs of global warming.

While global warming refers to an overall trend, its impacts will be far from uniform. Land, for instance, will warm more quickly than water. Moreover, temperatures will increase more at the lower than the upper end of their ranges, so that night and winter temperatures will rise much more than day and summer temperatures. Likewise, temperatures will be raised in temperate and Arctic regions much more than in tropical areas.

In all the negative publicity about global warming, it is easy to overlook potential benefits in at least some locations. Less energy will be needed to heat buildings, previously infertile lands of high latitude will start producing crops, and there will be less suffering from debilitating cold waves. Increased CO_2 might also make crops grow faster. On the down side, there will be more frequent and more intense heat waves, air conditioning costs will rise, and previously fertile areas in the subtropics may become unusable (Emanuel, 2007). There will definitely be winners as well as losers.[13]

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the cause of warming during the last century, climate change scientist tend to believe that the historical evidence suggest that its contribution can only be small (Dessler and Parson, 2010). This last point, however, is the subject of much actual controversy. The most important discussion is about the role of clouds in determining climate. Even the IPCC acknowledged that cloud feedbacks remain the largest source of uncertainty. Most existing climate models employed to predict future temperature levels treat clouds in a way that amplifies the warming effect of carbon dioxide, but this treatment is much disputed.

[12] Note that the IPCC statement specifically avoids attributing pre-1950 warming to human activities, since the Earth has been warming for at least 400 years.

[13] Although small countries with relatively few economic sectors may be almost entirely winners or losers, large countries and/or those with widely differing microclimates may experience dramatic and unpredictable reallocations of losses and gains. Directing public sector resources to new and/or increasingly afflicted losers—and away from newly made winners and the less needy—is likely to pose a challenge to national institutions. Previous work undertaken by and/or in association with IDB researchers on politics and institutions, as well as the role of interest groups, could be usefully applied and extended in this regard. Of particular note are Stein et al. (2005), Chapter 10 of IDB (2010), and Scartascini, Stein and Tommasi (2010).

However, there are potential consequences of warming that might be catastrophic.[14] One is the potential high rise of the sea level. This mainly depends on the melting of the Greenland ice sheet, which is very difficult to predict (IPCC, 2007a). In its 2007 report, the IPPC estimates that sea levels will rise about a foot over the rest of the century. While this is not a trivial amount, it is also important to realize that it is certainly not outside historical experience. Since 1860, the Earth has experienced a sea level rise of about a foot.

The effects of the expected increase in sea level are likely to differ by location. Rising sea levels will mean that potentially many more people will be vulnerable to floods. This risk can be reduced, however, through appropriate investments in protection (adaptation) such as the Thames Barrier, which protects London from sea surges, as well as dikes, levees, and coastal protection. On rare occasions it may be advisable to surrender land to the sea.

Hurricanes, especially in the North Atlantic, might substantially increase their power. The increase of water vapor in the atmosphere will likely cause rain to increase in places that are already wet even while increasing the intensity, duration, or geographical extent of droughts. Thus, both flooding and drought will actually increase on a warmer Earth (Emanuel, 2007).

The melting of glaciers and other changes on Earth are also likely to affect the access to fresh water of large groups in society. If glaciers that feed rivers entirely disappear, for instance, while the overall amount of water available over a year would probably remain the same, but it would be distributed very differently, possibly leading to severe summer droughts. While this situation can to a large extent be remedied by improved water storage, addressing droughts will be a cause of serious concern in the developing world, including Latin America.

While there was in the twentieth century an approximately 3 percent increase in the amount of water flowing through the world's rivers, the IPCC is concerned that water supplies may display greater variability, both regionally and seasonally. Humans will have to adapt. Where water is in abundance, flood defenses need to be constructed to cope with wet seasons, as do water storage facilities for use during dry seasons. Where there is shortage, as there was in many places long before there was any hint of global warming, the remedy is to cut out the

[14] Two additional but highly improbable catastrophic occurrences could result from climate change. The first is a disruption of the Gulf Stream and possibly other ocean currents in the event of relatively precipitous melting of the Greenland Ice Sheet, with highly uneven global climate impacts that could paradoxically include dramatic cooling of Europe. The second is the melting of seabed methane ices, which in at least some models would further increase global temperatures as a result of increased GHG levels.

widespread wasteful use of water through sensible water conservation measures, especially including the correct pricing of water. Moreover, there has recently been encouraging progress in desalination technology, offering the promise of producing ample supplies of fresh water from the salt water of the sea.

In regard to food, the IPPC projects that production will increase as local average temperature increases over a range of 1-3 ^{o}C, but above that range food production is projected to decrease. Moreover, this is an area where the scope for adaptation is particularly pronounced.

The connection between global warming and health is murky. There are, of course, very serious health problems of many kinds throughout much of the developing world which need to be tackled in their own right much more urgently than they are being tackled at the present time. Once this is done, the potential adverse health effects of warming will diminish substantially.

Finally, as atmospheric CO_2 continues to increase, it is virtually certain that the oceans will become more acidic. This may have severe implications for ocean ecosystems. Indeed, climate change will, in general, affect natural or unmanaged ecosystems (IPCC, 2007a).

Considering this potential problems, it is important to note the following: First, most of the adverse effects of global warming identified by the IPCC are not new to the developing world. Drought, hunger and disease long existed in poor areas. Much the same applies to the flooding of low-lying coastal areas, though this tends to occur as a result of rivers overflowing their banks in the monsoon season rather than from sea-level rise. Thus, global warming is essentially projected to exacerbate problems that already exist. Second, adaptation can substantially reduce the adverse impacts of future global warming. Third, while warming may be global, any adverse effect is subject to considerable local variation. Thus, we need to examine climate projections at relatively fine regional scales, with consideration of local topography, ecosystems, and current climate. Although climate projections grow more uncertain at smaller regional scales, some broad regional results might help us intelligently tailor our response to climate change.

Thus, one key input in the whole analysis is to produce a study that outlines the best forecast of outcomes for the different scenarios by regions within LAC. We need to precisely establish the plausible future scenarios in terms of climate change and its consequences for Latin America.

3. Adaptation and Mitigation

There are, of course, many actions that can be taken to manage the climate change problem. Some of these actions are best performed by governments, such as mandating emission reductions or investing in more resilient infrastructure, while others are best undertaken by private agents acting on their own, such as adapting production practices to a changed climate.

The general category of mitigation encompasses a variety of actions and policies. They can contribute to reducing greenhouse gases emissions or increasing their capture from the atmosphere and thus reduce the probability of adverse shocks due to climate change. Adaptation, on the other hand, stands for actions that anticipate and/or compensate for the potential adverse effects of climate change.

The most obvious way of managing climate change is to reduce emissions of greenhouse gases (GHGs) into the atmosphere, particularly CO_2 from fossil fuel combustion. Technologically, this objective involves either reducing the use of carbon-rich fuels or using technology to reduce emissions of GHGs from what otherwise would be the case. Removal of GHGs from emissions streams is technically feasible, and there is increasing interest in this technological option for managing climate change in the longer term (Kim and Edmonds, 2000, and McFarland et al., 2001).

An alternative approach is geoengineering, which would involve large-scale engineering of the environment to reduce the impacts of climate change directly. The menu of possibilities is lengthy (Marland, 1996, Schneider, 1996, and Schelling, 1996).[15]

Public opinion and public policies at both the local and international levels seem to be biased towards mitigation rather than adaptation. Efforts to "save the planet" represent a seemingly plausible objective, and one that triggers proactive initiatives. At the international level, industrial interests are more likely to obtain financial resources for joint projects in mitigation than in adaptation efforts, relegating the latter to secondary importance. Perception of risk seems to be less clear in the case of specific calamities than that of a possible worldwide catastrophe. But perceptions play a key role in migration, investment and exposure to risk, as well as in preferences regarding insurance and public policies.

[15] It should be noted, however, that initiatives in geoengineering might be controversial because of potential direct and indirect costs, as well as unintended consequences in complex systems. Concerns regarding international and maritime law may also arise, as may concerns regarding institutional mandates and design.

Moreover, mitigation expenses are matched by international aid, and therefore the finances of national governments are jeopardized to a lesser degree than in the case of adaptation expenses. This further biases national-level political administrations in favor of mitigation rather than adaptation.

Whether this is also true for local communities remains to be seen. The most relevant question in this regard is whether adaptation expenses can be postponed or forgone under conditions of local minimum regret, and whether more probabilities and consequences can be more nearly determined before action is taken.

At the international level, the accepted point of view is one of minimum regret and cost effectiveness. But if the initiatives for containing GHG emissions are not successful, or if the limits for emissions have been calculated incorrectly, adaptation will be a necessary form of self-insurance.

As previously mentioned, there exist clear lists and rankings of alternative mitigation expenses (see, for example, McKinsey, 2009). A corresponding list and ranking for adaptation expenses for the countries of Latin America and the Caribbean still needs to be constructed. That list should rank adaptations in terms of costs and financial needs, and in terms of potential risks and impacts of climate change. Otherwise, spending in mitigation and adaptation will not be driven by sound economic principles and a cost-efficient policy will not be possible.

Mitigation and adaptation expenses, however, are not necessarily mutually exclusive, and in several cases they can be complementary. Additionally, they could be complementary of regular public and private regular investments.

One corollary to this insight is that the IDB must base its initiatives on an exhaustive list of properly ranked alternatives, with their costs and expected outcomes. A second is that, in the absence of such a list, policymakers risk a costly overlapping of efforts in data collection, case studies and formulation of proposals.

Next we shall develop a simple model to organize the discussion. The objective is to help identify the main elements of the analysis and the potential trade-offs involved in policy decisions. A priori, it can be said that climate change shocks and policies can produce reallocation of resources, modify the trade balance result, reduce the standard of living, worsen income distribution and endanger fiscal sustainability.

Those issues deserve to be examined in a consistent economic framework. Our model also addresses some of the other relevant dimensions mentioned above, particularly the following:

1) the gains or losses of advancing or postponing adaptation expenses due to the balance between expectations of learning or the ex-post costs of adjustment,
2) the trade-offs created by mitigation expenses, in terms of weighing benefits of international aid, penalties for lack of action with respect to alternative uses for the resources of the economy.

3.1 A Simple Model

We consider a simplified economy with a representative agent and one production sector that is open to international trade. The climate operates on the economy through several channels, which we present as specific cases. We work with a two-period economy.

We emphasize the following questions: (a) the direct impact of climate change on welfare, (b) mitigation versus adaptation expenses and trade-offs with direct consumption, (c) dilemmas created by the international agenda in terms of positive and negative incentives, and (d) the availability of appropriate infrastructure to cope with climate change.

We also try to make explicit the dilemmas faced by a typical LAC economy: (a) problems of political economy, (b) international negotiations, (c) allocation of resources and (d) design of institutions.

The economy will be allowed to make the choice of expenses that will help to mitigate climate change as well as to adapt to climate changes; so the presentation combines market rules with the social planning process required by the environmental question.

In one of the cases, the economy will be allowed to postpone decisions on adaptation expenses to gain flexibility and learn more about the shock. We shall discuss two scenarios. The first assumes that adaptation and mitigation expenses have to be anticipated, and the second that they can be postponed. Irreversibility of decisions and learning play a relevant role for society's choice.[16]

[16] See Ingham, Ma and Ulph (2005a), who follow the initial study of Ulph and Ulph (1997). Ingham, Ma and Ulph (2005b) consider the possibility of complementarity between adaptation and mitigation.

Case 1: Adaptation Expenses Cannot Be Decided Ex Post

The utility function of the representative agent is given by:

$$EU = U(C_0, M_0, G_0, A_0) + \{(1 - H)\, U(C_1, M_1, G_1, \alpha) + H\, U(C_1, M_1, G_1, \beta\,(A_0)\}/(1+r)$$

Notice that this is an expected utility, and that the probability of a negative shock is given by *H*. $\rho = \alpha$ or β represents the standard of living. We assume that in the good state of nature, the utility of the representative agent is always greater than in the bad state of nature—i.e., $U_\rho > 0$ and $\alpha > \beta$ for all possible values of *A*, which represent society's expenditure in adaptation to climate change. Naturally, β_A is positive (and β is a strict concave function).

C_i stands for consumption of domestic goods of period *i*, M_i for consumption of imports, G_i for government spending in social welfare unrelated to climate change and A_i, as mentioned, indicates expenditures in interventions in adaptation to climate change. With *r* we indicate the discount rate.

In this scenario it is assumed that decisions are taken at the beginning of the first period and cannot be revised with the arrival of new information.

The equilibrium conditions in the market for goods are given by:

$$C_0 = F(K_0) - I - X_0 - (G_0 + G_m + A_0)^{12}$$

$$C_1 = F(K_0 + I) - X_1 - G_1$$

Here *X* stands for exports and *Gm* is expenditure in climate change mitigation interventions.

Notice that the investment realized in the first period is included as part of the capital stock in the second period, where we ignore depreciation of the stock of capital. Also, for the sake of simplicity, we do not allow the economy to borrow (lend) resources from (to) the rest of the world.

Developed countries' incentives for adopting mitigation expenses are included in the period 0 trade balance condition as:

$$X_0\, P^*(G_{m,}, G_m^*) = P_m\, M_0 - Y\,(G_m\, E)$$

$$X_1\, P^*(G_{m,}, G_m^*) = P_m\, M_1$$

The rationale for the inclusion of *Y* is that the international community has moved towards the construction of a set of financial incentives to stimulate expenses in mitigation in developing countries, and those expenses in mitigation *Gm* and total emissions *E* are taken into

account. Though LAC is not a big producer of greenhouse gases (GHG), the region has the potential for mitigation at comparatively low costs.

We also allow for the possibility that expenses in mitigation, both local and from the rest of the world, affect international prices *P**. We develop this issue further below.

Assuming the society spends in adaptation, A_0 is determined by the following optimality condition which equalizes the marginal gain (in terms of expected present utility) of spending in adaptation with the marginal costs (also expressed in terms of expected utility):

$$U'_{A0} + [H\, U'_{\beta}\, \beta'_{A0}/(1+r)] - U'_{C0} = 0.$$

Again, the choice of mitigation expenses G_m is guided by the following optimality condition:

$$- U'_{C0} + U'_{M0}[X_0 P^{*\prime}_{Gm} + Y']/P_m + \{[(1-H)U'_{M0}(\alpha) + H\, U'_{M0}(\beta)]/(1+r)P_m\} X_1 P^{*\prime}_{Gm} = 0.$$

To gain insight, let us first assume that mitigation does not affect *P**. Then, this optimality condition simplifies to:

$$[Y'/P^*] - 1 = 0$$

This equation states that the country will increase its expenditures in mitigation up to the point where the specific financial aid (in terms of domestic goods) compensates for the total marginal cost of the intervention.

Additionally, if the rest of the world could penalize the domestic country's lack of mitigation expenses through affecting the international prices of its exports, there would be an extra incentive for the country considered to invest in mitigation. This additional effect is captured by the marginal expected gain of additional imports—since, by assumption, all mitigation is done with domestic inputs.

Finally, note that we have assumed that mitigation expenses are not seen as effective to prevent climate change. In general, this is a good assumption for LAC. But it could be possible that some specific interventions, such as preserving Amazonia, may be significantly effective. In that case, we need to include this extra positive effect in the analysis as follows:

$$- U'_{C0} + U'_{M0}[X_0 P^{*\prime}_{Gm} + Y']/P_m + \{[(1-H)U'_{M0}(\alpha) + H\, U'_{M0}(\beta)]/(1+r)P_m\} X_1 P^{*\prime}_{Gm} + (U(\beta) - U(\alpha))H'(G_m)/(1+r) = 0.$$

Case 2: Adaptation Expenses Can Be Postponed Until After the Shock is Observed

In this scenario we admit the possibility that the agent could observe the shock before engaging in second-period consumption, and the model has to be solved backwards. Therefore, through sacrificing consumption, he can improve his standard of living by increasing expenses in adaptation. So, there is a higher degree of flexibility, since adaptation expenses can be determined—for the second period—after the shock occurs. Learning is not modeled explicitly here but is a motivation for this exercise; society could learn about the probabilities as well as the consequences of climate change and revise its decisions accordingly. For the sake of simplicity, we shall assume that expenditures in imports and public spending are not reversible, so they are committed in the first period as in the previous case.

Expected utility is now given by:

$$EU = U(C_0, M_0, G_0, A_0) + \{[1 - H)\, U(C_{11}, M_1, G_1, \alpha(A_0, A_{11})) + H\, U(C_{12}, M_1, G_1, \beta(A_0, A_{12}))\}/(1+r)$$

The need for urgent compensation for a shock is represented as a quadratic function of the difference between adaptation expenses in the second period and those considered necessary after the shock is observed. They are justified in the presence of time-to-build or in the need to accelerate expenses in a short time.

When the good state of nature happens, the compensation will be given by A_{11} and hence:

$$C_{11} = F(K_0 + I) - X_1 - [G_1 + A_{11} + v(A_{11} - A_0)^2]$$

The ex post adaptation expense is likely to be low or zero, but it will be determined after observing the actual state of nature to maximize $U(C_{11}, M_1, G_1, \alpha(A_0, A_{11}))$.

Ex post, A_{11} will be determined by:

$$U'_{\alpha}\, \alpha'_{A11} - U'_{C1}(\alpha)[1+2v(A_{11}-A_0)] = 0.$$

From the perspective of the first stage, consumption in the second period will be a function of I, A_0 and v.

When the bad state prevails, the country must probably increase its expenditure in adaptation. At variance with the first case, a bad surprise creates additional costs since the economy had not taken precautionary action.

Therefore the market equilibrium for goods becomes:

$$C_{12} = F(K_0 + I) - X_1 - [G_1 + A_{12} + v(A_{12} - A_0)^2]$$

Now, the optimality condition for adaptation in the second period will be determined by maximizing $U(C_{12}, M_1, G_1, \beta (A_0, A_{12})$ subject to this last condition. Again, consumption and adaptation expenses for the second period will be determined ex post as a function of decisions taken in the first period.

As expected, a higher rate of discount and a higher marginal cost of public funds discourage adaptation expenses in the first period. A higher probability for the bad state of nature instead favors it, as well as the marginal cost of urgency.

When choosing A_{12} we now have the condition:

$$U'_{\beta}\, \beta'_{A12} - U'_{C1}(\beta)[1+2v(A_{12}-A_0)] = 0.$$

In this case probability *H* is no longer relevant, since adaptation expenses are postponed after observing the state of nature. However, the marginal cost of adaptation expenses now includes additional last-minute expenses.

The discount rate is irrelevant, since all happens in the future (expenses and gains). However, the fact that consumption and adaptation expenses of the second period depend from the decisions taken in the first period will have to be included in the program of optimization of the initial stage. For example, assume that they have no impact when the state of nature is the best one, but have influence in the worst case. Then the optimal level for A_0 will require:

$$U'_{A0} - U'_{C0} + H\, U'_{\beta}\, \beta'_{A0}/(1+r) + H\, \{-U'_{C12}(\beta)[1+ v(A_{12}-A_0)2] + U'_{\beta}\, \beta'_{A12}\}(\partial A^*_{12}/\partial A_0)\}/(1+r) = 0.$$

The expression $\partial A^*_{12}/\partial A_0$ indicates that the ex post adjustment is taken into account in the first stage.

The presentation above is a simplification and several effects can be included. For example it could be expanded to include the variables described immediately below.

a) Shocks to Production

The analysis can be specialized to the case of shocks to production. Let us assume that the shock is multiplicative and impacts on $F(K_0+I)$ through a random variable γ that takes the value of 1 in the good state of nature and less than 1 otherwise. Let us assume that adaptation expenses can

compensate for the shock by increasing the ex post value of γ, i.e., $\gamma'_{A0} > 0$. Then, if we limit the analysis to Case 1, the adaptation expenses will be undertaken when:

$$- U'_{C0} + H\, U'_{C1}(\gamma)\, \gamma'_{A0}/(1+r) > 0.$$

b) Productivity of Adaptation Expenses

On the other hand, it is plausible to consider that adaptation expenses can contribute to production. That can be represented by assuming that a proportion φ of A_0 enters into the production function for the second period, i.e., $F(K_0 + I + \varphi A_0)$. This will increase the social value of those projects.

c) Transfers of Technology

Additionally, one of the incentives to participate in international mitigation projects is the possibility of obtaining transfer of new technology that could increase domestic productivity. In our case, that can be represented as a multiplicative increase in the production function, e.g., $\theta(G_m)\, F(K_0 + I)$, with $\theta'(G_m) > 0$.

3.2 Some of the Trade-Offs and Dilemmas that the Model Reveals

Intermediate processes use a fraction of total production so that the market for goods in each period has to be written as:

$$C_0 = F(K_0)(1 - \eta) - I - X_0 - (G_0 + G_m + A_0), \text{ and}$$
$$C_1 = F(K_0 + I)(1 - \eta) - X_1 - (G_1 + A_1).$$

Then GHG emissions can be assumed to be proportional to consumption, exports, total production and intermediate consumption:

$$E = \varepsilon_F F + \varepsilon_\eta\, i(\eta, F) - z(Gm).$$

In this expression the ε's stand for physical coefficients of emission of GHG from production and intermediate uses. Thus, the function $i(\eta, F)$ indicates the emission from intermediate production. An improvement in quality of intermediate processes could therefore be represented as a reduction in ε_η. The function $z(Gm)$ indicates the possible success of mitigation in reducing emissions (z'_{Gm} is non-negative). This representation is clearly a simplification, since climate change and human impact on it is still subject to scientific debate, as mentioned above.

There is a supply of foreign aid that takes into account expenses in mitigation, coefficients of emission of GHG from production, and total emissions, technological substitution as well as the effort of the economy to address climate change:

$$Y = Y\,(Gm, \varepsilon_F, E),$$
$$Y_{Gm} > 0,\ Y_{\varepsilon F} < 0,\ Y_E < 0.$$

As noted above, the international community has moved towards the construction of a set of incentives to expenses in mitigation in LAC region. Though LAC is not a big producer of GHG, the region has the potential for mitigation at comparatively low costs.

Maybe one of the challenges for the international agenda of LAC is how to go from $Y = Y\,(Gm, \varepsilon_F, E)$ to something like $Y = Y\,(Gm + A, \varepsilon_F, E)$. It has to be taken into account that aid for mitigation could replace or defer aid for other goals and will not necessarily imply additional help.

Prices of exports could also be a function of mitigation expenses relative to emissions:

$$P^* = P^*(Gm, \varepsilon_F, \varepsilon_\eta, Gm^*),$$
$$P^*_{Gm} > 0,\ P^*_{\varepsilon X} < 0,\ P^*_{\varepsilon\eta} < 0,\ P^*_{Gm^*} > 0.$$

In words, mitigation expenses might increase the price of exports; this assumption represents the gains from reduction of the price due to the attributed carbon content of exports or to the process of their production. On the contrary, when emissions due to exports are high, the expected price will be lower; the same will happen if exports are produced with processes that increase the emission of GHG. Finally, expenses of the rest of the world in mitigation can potentially increase expected prices due to gains in competitiveness.

The perception of the region of the effectiveness and commitment of the rest of the world, through *GM** for example, therefore becomes a relevant element. Reciprocally, the rest of the world may have expectations of regional actions. This is the subject of much of the present controversies and negotiations. Moreover, the announced *Gm* or *Gm** and the actual figure may well differ.

The knowledge of the specific structure of these last two functions is not necessarily precise. Not only is the influence of human activity on climate not well understood, but it is also not fully known how adaptation can protect welfare and the stock of capital and infrastructure. Moreover, the identity and location of those stocks are not always known.

Expenses in cutting GHG emissions are expected to result in both higher costs of production and higher prices of exportable goods. The optimal level will equalize marginal costs and marginal revenues.

At the level of the government, optimal emissions reductions could be higher or lower. Governments have to take into account the possibility that environmental aid could be a way for obtaining additional funds without paying the marginal cost of public funds. But commitments due to international agreements might require deeper reductions, and mitigation expenses could be too costly for society (in terms of employment, for example). Additionally, lack of enforcement could result in higher emissions than planned. This could contribute to failure in meeting international commitments and open the way to costly sanctions.

It is interesting to notice that when incentives are present, individual agents take the initiative in adaptation expenses. According to CEPAL (2009), that seems to be the case in agriculture, where spontaneous investments have been observed. Complementarity or substitutability between public and private policies is important to minimize total costs.

But in principle, unless effects on prices and aid are positive, optimal mitigation expenses for individuals are expected to be zero.

Thus, public policies will have to take into account the following considerations:

- Actions are not taken by a sole individual who acts perfectly coordinated with himself.
- It is necessary to consider compensations both between agents and through the government,
- The reaction of private agents in the market has to be considered since relative prices could be different before and after the action, and therefore a second-best solution would be necessary (analogous to optimal Ramsey taxes).

4. The Path of the World

The international community has implicitly agreed to a strategy of minimum regret and cost effectiveness. The goal is to reduce emissions to lower the probability of going beyond a dangerous threshold of temperature increase and to do so efficiently.

Multilateral institutions also maintain that the challenge of climate change has to be faced without jeopardizing advances in development, and that much can be done through transfer of technologies and financial aid.

At the heart of economic policy must be the recognition that the emission of greenhouse gases is a market failure: the social cost of the goods that produce emissions of greenhouse gases is higher than their private costs. The appropriate response to a market failure is not to abandon markets but to act directly to fix them through taxes, other forms of price correction, or regulation. Of course, the magnitude and difficulty of this issue cannot be ignored, as greenhouse gas emissions constitute the greatest market failure the world has seen.

The central economic criteria in forming policy must be: effectiveness in reducing emissions on the scale required; efficiency, to keep costs downs; and equity, in recognizing differences in incomes, technologies and historical responsibility (Stern, 2007).

Nordhaus (2008) argues that an efficient solution to the problem or global warming requires that the marginal costs of reducing CO_2 and other GHGs should be equalized in each sector and country, and that in every year the marginal cost should be equal to the marginal benefit in lower future damages from climate change. His simulations nevertheless suggest that even if an efficient solution such as this were attainable, the price of carbon should increase substantially, though gradually. The only realistic way to achieve this efficient solution is by imposing harmonized carbon prices that apply everywhere, with no exempted or favored sectors or excluded countries. The second requirement is that the timing of emissions reductions be efficiently designed. All policies implemented so far have failed to meet these two key criteria.

For Latin America, the most important question in terms of mitigation is to foresee where developed countries are heading in terms of global warming policies. Clearly, in terms of emissions of greenhouse gases, Latin America is of little relevance in the world strategy: it will represent only 15 percent of the total as of 2012, with Brazil accounting for half of that figure and the other half largely concentrated in four countries. (Paradoxically, though LAC countries do not contribute substantially to global warming, some of the cheapest solutions might be in their hands.) In the meantime, whether China builds 1,000GW of coal-fired electricity generation and whether it adds half a billion cars with conventional engines is of an order of magnitude more important to climate change than virtually any other trend.

With the existing technology, enacting an aggregate program of credible carbon emissions reductions consistent with stabilizing emissions at the 450-550 ppm carbon dioxide equivalent concentrations appear quite difficult. Allowing for population growth, it requires a two-thirds fall in per-capita emissions by 2050 to about 2-2.5 tons carbon dioxide equivalent by that date, and developed countries' annual per capita emissions range from 10 to 20 tons. The challenges to this undertaking are immense, and at its core lies a version of the prisoner's dilemma: it is in the interest of each country that others reduce emissions without having to do so itself. In order to improve the incentives of a system of emission restrictions, developed countries might need to rely on import taxes and/or trade restrictions. Of course, the problems of implementation of such a strategy would be substantial. More importantly, even China's substantial export sector represents only one third of its GDP. Thus, developed countries only have limited influence over the developing world (Klemperer, 2010). Matters are made worse by virtue of the distributions of costs and benefits. Some countries arguably actually gain from a warmer climate, while others are badly affected.

The present strategy of reducing emissions is the basis of the Kyoto Protocol, which was intended to be a first step toward a more comprehensive international solution. Kyoto requires small reductions (about 5 percent on average) in the emissions of industrialized countries for a short period of time. Kyoto was to be followed by a sequence of other agreements, with each new agreement progressively lowering the limit on the emissions of countries. Eventually, it was hoped, every country would be subject to an emission cap that would correct the previous market failure.

Unfortunately, as it stands the Kyoto Protocol is unlikely to produce a solution to the problem of climate change. First of all, it has so far failed to attract broad participation. Second, it neither creates incentives for compliance nor seeks a substantial reduction in emissions. Indeed, it is designed in such a way as to exclude the most important components of emissions. The agreement's basis in geographical production, excluding aviation and shipping, shapes negotiations in an inherently conservative and inefficient way. So even if tighter geographic production caps are agreed upon, the net result for developed countries will not meet the scale of the task, and developing countries (which produce and export carbon) will consequently find themselves asked to do proportionately more than their own carbon consumption dictates.

In any event, however, Kyoto matters little for the climate. Even if all countries had ratified it, and all countries lived up to their commitments and stuck to them throughout the twenty-first century, and assuming that this would not produce a mere geographical displacement of emissions—an issue that needs to be revisited in future agreements—the change in climate would be minuscule. The expected increase in temperature by the end of century will be delayed by about five years, from 2100 to 2105.

Most importantly, a binding global agreement to reduce emissions is not presently possible because the major developing nations, including China and India, have made it clear that they will not be signatories to any such agreement for the foreseeable future. The basis for this position is twofold. First, those nations' per capita emissions, though now rising rapidly, are well below those in the West and will remain so for several decades. Second, and more importantly, their overriding concern is to lift their populations from poverty by the fastest possible rate of economic growth; a sharp increase in energy prices would seriously hinder this project (Lawson, 2008).

As a result, large-scale R&D programs are likely to have a greater more impact on the climate-change problem than any other course of action (Klemperer, 2010).[17] Ultimately, the world will be unlikely to reduce the use of "dirty" energy sufficiently unless it can find a cheap, clean, substitute. This requires innovation. Alternatively, innovation could lead to the development of cheap technologies for removing dioxide carbon from the atmosphere.

Thus, in order to design alternative mitigation policies for LAC countries, it is necessary to understand the overall direction of global mitigation efforts. From the LAC perspective, enacting emissions-reduction regulations is motivated by either i) the prospect that developed countries will compensate LAC countries for the costs involved, an area in which Latin America might have comparative advantages; or ii) the expectation that trade costs will greater than the costs of reducing CO_2 emissions. Instead, if the developed world concludes that the only viable mitigation strategy is to invest in R&D, LAC is likely to participate in this process only as a user of the new technologies developed. In either case, low-carbon paths can be reached without jeopardizing development if transfers of funds and technology are available, as well as funds for adaptation (World Bank, 2010). Thus, we need to study this issue in further detail: What policies

[17] See also Acemoglu et al. (2010).

and strategies to deal with global warming will the developed countries plus China and India adopt, and what role are other developing countries likely to play in that strategy?

However, LAC will need to be proactive in R&D for regionally specific adaptation; for example, climate change can trigger diseases of crops and cattle as well as of humans. It thus seems advisable to allocate resources to the assessment of potential courses of action (e.g., development of vaccines and control of vectors of transmission for example). Those resources will not be provided by the international community, since they address specific shocks rather than general conditions.

5. The Choice for LAC Societies

From the perspective of these discussions, the Region's economy faces several dilemmas. The model and the above discussion of the path of the world can help to guide the analysis for the climate change agenda for LAC by taking into account the following elements:

- *The social problem and environmental sustainability under allocation through private markets.* Expenses in adaptation and mitigation respond to a social decision but are implemented through markets. Changes in relative prices and in rewards to factors can offset or reverse the initial effects.
- *Possible sanctions and international trade.* Negotiations and international incentives, as well as certification, make prices of exports (and imports) a function of domestic expenses in mitigation. When border taxes based on carbon content are imposed, the economy faces lower prices P*(1 – t) where *t* is determined on a conjectural basis of emissions (*P** has the level of emissions as an argument); and one of the problems is that the proceeds are revenue for the rest of the world. The alternative is to impose a domestic tax that could be used to substitute for a change of technology, to make ε_F and ε_α endogenous, for example, or to subsidize expenses. Certification, which limits opportunism in the conjecture for *t* border taxes, is also an issue that requires resources and has to be included in the equations above.
- *Lack of data.* The evaluation of the relevance of climate change shocks and policies could help to generate estimates of the relevance of effects and consequences. Without this information—which this task demands in great

volume—the main equations of the social decision process cannot be expressed, and it is not possible to solve for government expenses and to have an idea of relevance. With or without a model, implicit evaluations are made by political leaders and policymakers.

- *Migrations.* Migrations change the supply of labor and impact on the production function *F*, but they can also influence welfare and put infrastructure under stress. It is critical to determine whether migrations respond to shocks and to distinguish between temporary and permanent incentives to migration.
- *Health.* Climate change shocks are expected to influence human health through a variety of channels, with effects on welfare and the availability of human capital, as well as possible reductions in productivity. Adaptation in this case requires additional expenses in sanitation and water availability, and even in health sciences research to anticipate the diffusion of endemic diseases in the region.
- *Institutions and enforcement.* Well-designed policies can fail in a context of weak institutions and insufficiently powerful incentives, and in many cases LAC countries suffer from endemic institutional weakness that make it necessary to consider second-best policies or sensible policies adapted to actual rather than ideal circumstances. This will affect prices of exports and reduce the productivity of mitigation and adaptation expenses.
- *Energy and transport.* Changes in the relative prices of energy and transport almost inevitably affect industries' activity levels and costs, and they may also influence unemployment and the welfare of the poor. The net effect on the poor, who devote a significant share of their income to those goods, remains to be determined.
- *Shocks to infrastructure.* Shocks to infrastructure will impact capital and modify the productivity of the economy in a variety of ways. Adaptation cannot be seen exclusively in terms of infrastructure and direct impacts on households' standard of living.

- *Forestation and agriculture.* Much of the potential of LAC to contribute to global mitigation of GHG emissions and sequestration of CO_2 in the atmosphere resides in these sectors. However, current efforts may respond more to an international agenda focused on energy, transportation and substitution of technologies in manufacture.
- *The political economy.* Even if optimal policies are identified, putting them into practice requires the approval of societies and of the political system. Interest groups of interest could block reforms or make their implementation more costly.
- *Market for insurance.* Adaptation can be thought as a form of self-insurance or remedy to address possible calamities. Catastrophic changes could make insurance completely unaffordable for the private sector, and even for individual countries. Among adaptation expenses, precautionary investments in infrastructure as well as domestic R&D on specific diseases of humans, crops and livestock could be included.
- *Consistency of ex ante plans and ex post realizations.* In terms of the model, F different from γF could necessitate reinforcement of the stabilization role played by governments and by financial institutions such as the IDB.
- *Market for carbon.* Though cap-and-trade and tradable allowances provide some flexibility, it is not clear that they have distinct advantages under conditions of macroeconomic instability and weak enforcement. A market for carbon would create additional costs for firms, of the form $P_c\ \varepsilon_F\ F$, where P_c is the price for carbon. That price will be determined in a market so that $\varepsilon_F\ F = TA$ (or $E = TA$) where TA is the quota of total allowances conceded (as a gift or through an auction) for emission of CO_2. The initial distribution of endowments will modify income distribution and industrial structure.
- *Poverty and transfers.* If a condition of minimum standard of living is imposed, then shocks and policies could stress the economy, particularly after shocks that could reduce productivity or even prices P^*.
- *Technological substitution, factor rewards and trade performance.* Aid links Y to ε_F and E, but it could also modify F and F_K. Changes in production and in

- *Fiscal imbalances.* It is not enough to consider that revenues are normally costly, in the form of the marginal cost of public funds. Moreover, it is uncertain whether revenue objectives will be met under macroeconomic shocks and financial distress.

To address some of these elements, it will be necessary to elaborate the model further and increase its dimensionality (e.g., including two or more production sectors, rural and urban areas and agents, or more than one decision-maker). It should additionally be noted that several of the items listed above are interlinked, such as enforcement and design of institutions.

6. Adaptation: Self-Protection and Insurance

The effects of climate change on infrastructure, resources, health and water and food security are difficult to predict. Historical data are of little help, and the diffusion of human activity over the planet has not been designed to take the impacts of climate change into account. Therefore, present action has to be oriented toward anticipating shocks, protecting assets (both human and physical) and compensating for damage.

Assessment is further complicated by the inherent complexity of the dynamics of climate, causality and meteorological events. The frame of the decision problem is therefore closer to a case of uncertainty rather than one of risk; moreover, it can be said that it is one in which some potential states of nature are beyond the a priori evaluation of agents, who thus do not take self-protective action.

As Keane et al. (2009) put it, "the only certainties about the impact of climate change on agriculture are increasing uncertainty, variability and frequency and severity of extreme events." Even human responses to the problem, including mitigation and adaptation expenses, have uncertain outcomes.

In terms of the model presented above, H is a probability that encompasses a distribution function, and its accurate determination and support are difficult to determine.[18] Also, the effectiveness of expenses G_m is not well established (and difficult to rank).This adds difficulties

[18] Pindyck (2009) appraises policies with heavy-tailed distributions.

to the optimal mix to be identified by any social planner, who has to take into account that adaptation expenses afford protection that is not obtained from G_m.

Moreover, risk spreading is difficult since the law of large numbers is not applicable: shocks are widely distributed, and there is high correlation of individual random shocks. Unfortunately, private markets for insurance can develop (or continue to function) only when the liability of insurance companies is limited and the law of large numbers does work, and there is a lack of interest in this market among private insurance companies. It is therefore possible that many of the risks from climate change will have to be insured or reinsured by national governments. Nonetheless, given the magnitude of the phenomena considered, national governments' limited financial ability to respond to environmental catastrophes is a matter of concern.

There are, however, examples of financial instruments designed by individual countries, with assistance from international institutions, to cope with environmental risks; some of these are surveyed by Gupta, (2008). Mexico, Turkey and Ethiopia, for instance, have introduced new insurance pools, bonds and derivatives. The Caribbean Catastrophe Risk Insurance Facility is further identified by the World Bank (2010) as a multicountry mechanism that can be used as a guideline. Consequently, regional institutions have a role to play in pooling resources to face the indivisible risk of climate change. That role and the magnitude of the financial needs still need to be assessed.

But not all insurance has to be implemented through financial instruments. Improvements in infrastructure, specific R&D, new regulations for location, and stricter building standards belong in the category of self-insurance tools, which are forms of adaptation.

As shown by this brief survey, and other sections of this paper, efforts to identify and quantifying mitigation alternatives (in terms of impact and cost) have been much more extensive than assessments of adaptation alternatives (also in terms of their effective impact and estimated costs). In contrast to the literature on mitigation, the literature on adaptation—while listing numerous plausible actions—does not rank alternatives according to economic or other criteria. As noted by Keane et al. (2009), one such asymmetry of effort occurs in the case of agriculture.

A further difficulty mirrors the regulatory dilemma of the Kyoto Protocol provisions discussed above. In the case of environmental insurance mechanisms designed for the national or international level (for example, in the case of regional mechanisms led by the IDB), the

relative willingness of large and small countries to contribute is unclear. How much countries are willing to contribute is uncertain as well.

Nonetheless, the potential advantages and disadvantages of a regional mechanism, such as a special fund to be used in the event of climate change negative shocks, must still be studied; such a fund could help to avoid the replication of individual countries' costs (sub-additivity) in self-protection. However, a regional mechanism should harmonize incentives to participate and prevent moral hazard on the part of potential victims, who could relax their standards.

Therefore, though it is clear that the creation of a market for insurance of wide spectrum (including sanitary intervention units, for example) could be valuable, the assessment of its costs, the definition of objectives and the processes to make it operative in practice are lacking. Future efforts will be needed to address practical issues of monitoring and verification, as well as quantitative estimates of contributions to any planned insurance fund. Data on which to base these analyses must also be assembled.

However, not all policies of insurance require the massive use of financial resources. Since adaptation and research and development in specific or local problems can to some extent be considered insurance policies, in at least some instances it may be advisable to take a wait-and-see approach before committing limited resources to prescribed courses of action. In fact, waiting to invest can be a dominant strategy when there are chances of learning more, resources are costly at present, the costs of regret are not high and time-to-build is not significant. However, protection with early alert systems, reliable anticipated measurements of coastal dangers and of tides, and more stringent building codes are examples of relatively inexpensive methods of insurance that can be applied even under low option value to wait.

It consequently seems advisable to identify viable opportunities and to explore the advantages and shortcomings of either developing a regional insurance system or providing IDB support to national systems.

7. Migration and Location

Certainly, the costs of global warming are lower if people relocate in response to the present change in climate, one of many in the Earth's history.

Throughout our planet's 4.5 billion years of existence, Earth as a whole has been indifferent to its average temperature. Life on Earth, as it has for several billion years, will

eventually adapt to most new situations. The question is whether we can now adapt to rapid change in climate, given all the constraints we face.

On the one hand, there is the issue of migration from the most affected areas. We need to understand what constraints might impede this natural response to an adverse change in the environment and evaluate if there are cost-effective policies to enhance that response. Issues of prime importance could include the following: asymmetric information, perception of the real duration of the shock (temporary vs. permanent), coordination problems, liquidity problems, and institutional constraints.

On the other hand, there is the issue of migration to areas that could be affected. The most salient situation being the trend observed during the last decades of people moving to reside on sea coasts since, as people becomes richer, they prefer seaside views. Moreover, cities can be put under stress by sudden massive migrations to urban areas.[19]

The big question here, as in similar cases, is whether we can identify those areas in advance and whether the individual decisions are fully informed and rational, and hence are internalizing the risks associated with global warming. If they are not, what policies should be enacted to correct for this failure?

8. International Trade

The interface between trade and environment has been under discussion for several years. Some of the more difficult and controversial issues had already been identified by the early 1990s (see, for example, Low, 1992): industrial location, competitiveness, standards, migrations and opportunistic use of trade barriers and tariffs. Climate change concern has reinforced the focus in the discussion of that interface and has opened new questions, as well as fostered interest in quantification.

Keane et al. (2009) maintain "poor countries with large rural economies depend on agricultural exports for their fiscal and socio-political stability …; agricultural exports earnings may be jeopardized unless alternatives are sought or 'climate-proof' investments are made." We could add that not only "poor countries with large rural economies" face a problem in LAC; large economies like Argentina and Brazil depend on the success of their agricultural products

[19] Furthermore, there is the possibility that areas more affected by climate change risks (such as flooding, extreme weather changes, diseases, etc.), whose lands and existing constructions will become cheaper, may attract poor people, thus aggravating risks and increasing potential adaptation costs.

for fiscal sustainability and growth. Moreover, in those countries a large proportion of their GHG total emissions are attributed to the agricultural sector.

Since it is accepted that cooperative action is not only convenient, but also necessary, international action on mitigation has been oriented to give several incentives for individual countries to participate in formulating the climate change agenda.

Up to now that action has included up special regimes of cooperation aimed at adopting standards and technological processes of more developed countries by less developed economies, and international aid has been tied to some actives initiatives of technological substitution. LAC countries, however, have not yet fully considered how the international climate change agenda might affect trade, a very sensitive area for the Region's macroeconomic and growth performance. Anticipation of scenarios and compensatory policies for trade could therefore be considered one of the possible adaptation policies.

Several costs, for instance, may take the form of incentives to change production choices. Compensatory taxes, taxes on transportation of export goods, and certification and labeling requirements (that could reduce net prices to exporting countries) are all instruments that will affect international trade. One of the most worrying aspects of these policies is their potential use as trade barriers, and LAC's concerns in this regard should be translated into effective actions to limit opportunistic use of environmental goals for protectionism.

Optimal climate change actions need to be supported by sustainable macroeconomic regimes, and the results of international trade are critical for that sustainability. Conversely, policies that address climate change issues but endanger trade balance sustainability would be unfeasible in the long run.

Some of the issues involved are the following:

1. Effects of carbon taxes on exports, when those taxes are adopted by countries that are traditional destination of the production of LAC economies, could greatly harm LAC economies (higher P^* imply lower benefits for the firms in equation (6)). Since taxes on exports tend to compensate for mitigation expenses of developed countries, LAC must determine whether it is to better to engage in business-as-usual—accepting those taxes which imply transfers of the proceedings or rents to the rest of the world—or adopting domestic policies.

The latter course encompasses two types of initiatives. The first involves imposing domestic taxes the on carbon content of exports, which will keep tax proceeds in the Region. Adopting this approach, however, would make entail deciding whether to do so unilaterally or collectively (as part of a regional trade agreement) in order to prevent trade deviations within regions, a problem arising from the distribution of proceeds. A second approach involves subsidizing or promoting technological substitution through means such as carbon markets. Alternatively, taxes could imposed on the estimated carbon content of final products or the content added at intermediate process of production; see Mattoo et al. (2009).

2. Air and maritime transportation, both for exports and imports, have been identified as an important source of GHG. Carbon prices or taxes imposed on them could discourage exports and favor domestic markets. A first appraisal indicates that there will be net losses for the LAC, given the distance to markets and that export goods are commodities.[20] Quantification is necessary to determine the net contribution of investments to improve logistics and to reduce GHG emissions.[21]
3. Present incentives to technological substitution are associated with financial cooperation offered by international institutions and developed countries. Much less has been done in terms of adaptation. Since cooperation is normally related to substitution of technology, the question arises of the real net contribution of those technologies to developing economies, as their endowments (e.g., less human capital than in developed countries) may not meet the requirements for successful technology adoption. Under these circumstances technology adoption should be treated as endogenous.
4. Reliable and independent certification and labeling is needed for the carbon footprint of products and/or processes. In order to confront the potential

[20] It is interesting to note that the World Bank's 2010 World Development Report raises an objection of an administrative nature to transport taxes, not one based on the costs of limitations to trade (see World Bank, 2010: 270).

[21] But again, the region as a whole could impose a uniform tax on air and maritime transportation, part of its proceeds would go back to the countries in proportion to the transport content of its international trade, and part would be used to fund collective activities of mitigation and adaptation.

opportunistic use of evaluations as trade barriers—or merely to simplify access markets abroad—LAC needs to develop credible labeling at a low cost, whether by a regional institution or other means. It seems advisable to assist the region in developing appropriate instruments, but the methodology and finance of the process have to be studied carefully.

5. Additional investment in "clean" technologies could put the trade balance under stress if those technologies require additional imports. This negative effect must be weighed against initial relief due to the financial aid and capital inflow due to potential migration of industries from developed countries with stricter regulation.
6. Changes in the value chain due to intermediate goods producers' environmental expenses could change the pattern of trade, even between countries within the region but with different policies on climate change.
7. Emerging potential controversies between members of trade zones, like MERCOSUR, regarding the use and determination of carbon prices or taxes on GHG will open new processes of negotiation with uncertain consequences for trade. The likelihood of a scenario of controversies and its potential impact on regional trade and welfare has not yet been assessed analytically.
8. Quantification is needed of the spillover of trade imbalances on the fiscal outcomes of several of the governments of the region, which depend directly (like Argentina) or indirectly on export taxes. The results will affect the welfare of both the urban and rural poor as well as modify the magnitude of investments and the introduction of technological progress.
9. Further analysis is needed on the impact on domestic and international migrations due to loss of food security (e.g., in or from Mexico and Central America) and their consequences on urban labor markets and on the capital account due to remittances.
10. Also needed is further evaluation of the effects of an increase in the international mobility of factors, including capital.

Quantitative assessments of the relevance of those issues could help to design anticipatory and compensatory policies, and to guide the actions of the IDB, since they would help to rank alternatives according to relevance. Reliable and comparable data would be a first necessary step. Up to now, the effort of quantification and data construction is fragmented, methodologies are obscure and data are not readily comparable. If this effort could be accomplished, even with not very sophisticated models that are transparent and consistent, the estimation of the relevance of shocks and policies could begin.

Additionally, there is a growing interest in trade in environmental goods and services, but that trade has not yet been precisely defined, nor the relevant regulation been examined. It remains unclear whether subsidies and technology transfer in this area are acceptable according to WTO rules and regulations.

9. Regional Trade: Problems of Harmonization

Regional Trade Agreements (RTAs) have spread rapidly since the late 1990s, and there are currently 300 formal RTAs notified to WTO and many other informal trade arrangements in force around the world. The convenience of this kind of agreements as opposed to multilateral negotiations has been the focus of recurrent academic discussions. One interesting result is that under RTAs external trade protection becomes more costly for two reasons: i) the economic marginal cost of external protection rises (due to trade diversion possibility) and ii) because the political-economy marginal gain from external protection falls (import-substituting companies already face competition from their RTA partners). Consequently, RTAs tend to reduce protectionist forces in the economy. At the same time, they have become a preferred form of reciprocal liberalization between countries and will very likely be in operation along with WTO liberalization efforts for a considerable time in the future.

RTAs may likewise be considered an instrument for climate change negotiations. In fact, analysts and governments in advanced economies have come to views RTAs as a potential positive instrument on framing trade and environmental discussions. Along these lines, OECD experts have provided a checklist on the recommended environmental provisions of RTAs.

However, the environmental aspects of RTAs are diverse, and an immediate parallelism between trade liberalization and environmental protection results should not be established without further analysis. For instance, Canada, the European Union and the United States have

included comprehensive environmental provisions in their recent RTAs. Among Latin American countries, Chile is the most active in this field.

MERCOSUR has also included environmental aspects in a specific side agreement that has resulted in rather weak regulations. Thus the forces operating behind environmental aspects may be very different as compared to the standard results of trade policy liberalization among partners. At the same time, multilateral commitments and instruments on climate change mitigation and adaptation still require thorough discussion. It is necessary to establish how trade issues linking WTO and RTAs can be compared to environmental aspects linking a global climate change agreement and those same RTAs.

The previous brief presentation raises several questions that are worth exploring:[22]

- Can the interaction between multilateral initiatives and RTAs' environmental provisions play a positive role in environment protection, as they seem to do in the case of trade liberalization?
- Is more progress needed in the coordination of initiatives that address climate change issues between members of RTAs?
- What are the key issues of this interaction (e.g., coordination of environmental regulations, new clean technology diffusion, and environmental regulation of regional trade in selected dangerous industrial sectors)?
- Will the results affect the composition, results and sustainability of RTAs?

10. Instruments and Markets for Carbon Emissions

Price and quantity instruments have been under discussion in environmental economics since Weitzman (1974) called the attention to their relative advantages and disadvantages under uncertainty. Uncertainty of costs and demand cannot be disregarded in the discussion of the optimal instruments to be used in LAC economies. Goulder and Pizer (2006) mention that empirical and theoretical studies show that the marginal benefits of avoiding damage are flat, and therefore that price instruments (as taxes) are preferable to quantity instruments (like quotas and

[22] Another topic worth discussing is whether regional trade blocs can strengthen their bargaining power vis-à-vis the developed countries in CC issues by acting collectively in sensitive issues, especially mitigation issues, such as forest protection and agricultural production technologies. As an example, a reduction of agriculture subsidies in the developed world and the imposition of taxes to contaminating technologies in the agricultural sectors of LAC may be a win-win mix, fiscally and environmentally, but takes regional coordination and international bargaining power.

tradable emissions allowances). From that point of view, LAC should move towards price instruments rather than quantities, and therefore not much effort should be put into the development of a regional (or national) market for tradable emissions.

But in practice the choice of instruments has to be made from a wider set, including subsidies, incentives to technological substitution, potential complementarities. In addition, several dimensions particular to LAC countries must also be examined, such as fiscal consequences, distributional impact, use of revenues, industrial structure effects, fragile macroeconomics and institutional weaknesses.

This perspective leads to the following considerations:

- A market for carbon would be difficult to develop to a relevant scale since efficiency of capital markets is not high and is permanently jeopardized by macroeconomic instability.
- There will also exist significant concerns about the initial distribution of allowances. If a method similar to the European were used, which emphasizes allocation to large incumbents, significant transfers of rents and distributional problems could arise (see CBO, 2000). Even in the case of European countries there have been serious concerns regarding the effective distribution of quotas by individual countries. A carbon market could also affect industrial structure and trade. Nor would an auction of allowances eliminate the dilemma of allocation of rents: should rents be returned to firms to subsidize technological substitution or should taxes that create losses of welfare be eliminated? A further problem in small economies is that incumbents could hold a large share of power so that the auction would not necessarily be competitive.
- Emissions quotas could be used to create barriers to entry; in such a case, cap-and-trade would give only a seeming flexibility, for the level of the quota could be used for strategic market goals.
- Subsidization of technological substitution per se could create fiscal problems, and its effectiveness for emissions control could be dubious: since it

stimulates entry the effect on final total emission is uncertain (Baumol-Oates result).[23]

- A tax on emissions would increase revenue and reduce emissions, but it could possibly be applied more easily on formal industries, thus creating an additional incentive to informality. Asymmetric treatments at either the national or regional level would therefore replicate the international controversies on competitiveness and arbitrariness in the estimation of the needed compensations, and complaints by those who follow the law.
- In all the above cases, quota enforcement could be impeded by an inefficient emissions control technology, thereby making price instruments more desirable in comparison.
- Since most of LAC's emissions come from agriculture and forest management, it would be necessary to develop instruments for those sectors. Carbon markets for carbon have so far not included agriculture, as doing so could make carbon prices plunge. However, were agricultural projects included, LAC countries could find a very direct and important way of gaining credits since significant proportions of their emissions come from agriculture. International action in this area seems worth pursuing.

A corollary to the findings above is that the analysis of instruments to date is far from providing a dominant choice. This leaves several issues to study:

- Which mitigation instruments are more effective and less costly for LAC countries?
- How would those instruments interact with other economic policy instruments?
- Should there be a harmonization of instruments for the region?
- Should the IDB support the creation of a regional market for carbon allowances?

[23] International studies show that a combination of push to technological substitution and taxes produces results superior to those of any of those policies alone.

The present and proposed allocation of funds for mitigation seems to be designed to show the effectiveness of exemplary cases. At a larger scale of action, it seems that this allocation should be undertaken following economic principles of cost-effectiveness, and the selection of incentives and controls is a necessary step in this process.

11. Institutions

As previously mentioned, social support is necessary for the success of climate change policies. Additionally, the institutional environment and the mechanisms that societies use to make effective policies and enforce them are very important. These areas represent a potential weakness for LAC in regard to accountability for policies agreed upon with the rest of the world, and they could have significant economic costs (in terms of aid linked to effective action, or in terms of prices of exports, for example).

At the international level, climate change policy includes incentives and expected sanctions, both implicit and explicit. Financial aid to technological substitution, for instance, is accompanied by potential border taxes computed on the presumed carbon content of exports. This action seems to follow the recommendations arising from academic research in the 1990s, which call for taking into account the difficulties of obtaining effective rather than nominal cooperation of countries, particularly those with weaker institutions, and therefore using more than one instrument to reach the desired goals.

As in a fractal, though, the big picture at a high level is likely to be replicated at lower levels. Some states will therefore find it difficult to enforce agreed-upon policies at lower levels, even if national authorities believe that climate change issues have to be addressed as soon as possible.

This pattern is a matter of both environmental and economic relevance, as the effectiveness of mitigation efforts that would reduce world temperature (or at least limit its increase) depends on collective action; isolated actions are both unlikely and of small impact. Moreover, access to financial resources will be conditioned on monitoring and verification of results; that is, from the point of view of individual countries of the region, financial aid will be jeopardized if domestic enforcement is poor. Unfortunately, LAC countries have a tradition of low enforcement standards. There is abundant evidence of tax evasion, informality, contracts renegotiations and breaks of the rules of law that confirm this assertion.

Enforcement will thus have to become much more robust and credible in the context of international mitigation efforts. If a carbon market is developed for the Region, emissions will have to be limited to the rights acquired, and it will also be necessary to control deforestation, even though forest protection is often in the hands of local authorities. No less indispensable will be controlling how financial aid is used to develop substitute techniques in agriculture.[24] An additional problem is that asymmetric enforcement could create within the region the same problems that are apparent at the international level.

There will probably be conflicts between countries that adhere to international standards and others who will prefer not to apply effectively the costly new rules. If migration of industrial processes is possible at the international level, it will be almost certain at the regional level when differential enforcement is applied. Due to competitiveness concerns, such migration will create an incentive for local authorities to relax standards.

Those problems will be a matter of discussion within trade blocs, and also within individual countries. For example, disputes are likely to arise between producers of different scales and location, many of whom will belong to the same value chain. It will further be difficult for many to abandon "business-as-usual." At least in the perceptions of small and medium-sized firms, environmental monitoring could be linked to tax monitoring.

Enforcement additionally involves the choice of price or quantities instruments in environmental economics, as well as the choice between command-and-control and incentives instruments. The choice between prices (whether taxes or other monetary incentives) and quantities depends on the relative elasticity of demand and marginal costs, and the source of uncertainty (costs or demand). Weak institutions and shallow enforcement add a new dimension that can be significant for the selection of an effective tool that maximizes welfare.

The situation can be framed in a principal-agent relationship. The principal is in this case the national authority and the agent, a local one. Command-and-control will be preferred over incentives when the principal can be seriously endangered by the agent's actions and monitoring is not expensive. Lack of water resources and their pollution, for example, endangers human lives, so it seems that command-and-control has to be used under a minimum regret perspective.

[24] G_m expected by a donor can differ from actual G_m. Then we would expect, in a broader international game, a change in P^* to internalize commitment problems.

Something analogous can be said of other resources, like forests, since their depletion could have worldwide consequences on the biosphere and their reconstruction could take decades or more.

On the other hand, incentives will be dominating when damage or losses are possible but not critical, and monitoring is costly. Pollution by manufactures or transports can be enforced through a system of taxes and subsidies (for technological substitution, for example) and subjected to random monitoring with a given frequency; deviations from expected standards could be corrected, without putting the society under an incommensurable risk.

The choice of the method of delegation depends then on the problem at hand and on the circumstances, but there is still work to do in the case of climate change.

Therefore, several questions arise:

- In what cases is a supranational authority necessary?
- Is it possible to use incentives?
- Are there cases that require permanent monitoring and direct control?
- Should national authorities delegate enforcement and control to local governments?
- Is it possible to cooperate under common environmental or economic borders?
- How will imports and exports be treated in the case of industrial processes that can migrate?
- How will macroeconomic conditions influence enforcement? How is it possible to compensate for short-run fluctuations that could compromise long-run results?

Moreover, there is no well-catalogued set of possible incentives, monitoring methods, trade-offs or cooperative actions to be evaluated and selected from. This area therefore seems to be a candidate for further analytical study.

12. Role of Financial Institutions

Funds available for mitigation clearly exceed those for adaptation. Lack of resources and the local and specific nature of adaptation thus put the burden of compensation on regional institutions (see World Bank, 2010: 22).

Relative abundance and the presence of numerous, dispersed initiatives in mitigation are also a challenge. Overlapping efforts might imply excessive competition for some sources of funds, and lack of access to others, as well as a non-optimal ranking of projects. Fragmentation of sources likewise does not help to make the process more efficient. The World Bank (2010) identifies 20 different bilateral and multilateral funds, each one with its own governance.

The Paris Declaration establishes a set of issues for financing climate change in developing countries, such as consensus, alignment of actions and priorities of countries, harmonization, comparable results and mutual accountability between countries (World Bank, 2010). In addition to addressing these issues, it is necessary to ensure the use of sounds economic principles in the selection of projects, as well as to act with transparency and equity. Further requirements including defining interaction with the private sector and exercising ingenuity in the creation of new financial resources. As poor design could be costly in the long run, there is a valuable role for multilateral institutions in these areas.[25] Therefore it seems recommendable:

1. To summarize the available funds and identify how the IDB can coordinate efforts for making access easier and more effective.
2. To develop common guidelines for the evaluation of projects of mitigation and adaptation.
3. To provide a toolkit for sectoral analysts, that could help to identify opportunities, assess their value under sound economic principles and to monitor the activities, with a common platform.

13. Agriculture

It has been estimated that more than a quarter of total CO_2 emissions could be reduced through less tillage of soils, better wetland and rice paddy management and better livestock and manure management (Keane et al., 2009). At the same time, present and anticipated future effects of climate change on LAC's agriculture must be addressed, in spite of uncertainty regarding their magnitude. Mitigation or adaptation policies will be the dominating choice depending on specific circumstances.

[25] There have been several criticisms on the Clean Development Mechanism, including financing reductions that would have occurred anyhow, weak governance, and efficiency cost of adaptation funding.

The most important direct impact of climate change shocks may be the effect on crop yields, with a wide range of possibilities for direct impact depending on type of production and region. Precipitation in LAC countries could change from +12 percent to -40 percent, and such changes are not without precedent. During the twentieth century significant increases in precipitation were observed in southern Brazil, Paraguay, Uruguay, northeast Argentina and northwestern Peru and Ecuador. Conversely, a declining trend in precipitation was observed in southern Chile, southwest Argentina and southern Peru; according to CEPAL (2008), and overall grain productivity could change between +5 percent and -30 percent by 2080.

In some countries, private producers have taken initiatives, such as the use of new crop varieties, to protect production from climate shocks.[26] These initiatives have been complemented by public policies, but the diffusion of knowledge (on new crop varieties, pest control and livestock vaccination, for example) is still limited in the face of new and possibly enormous challenges.

The vast area devoted to agriculture in LAC and the scale of production, however, make agriculture (along with forestry) one of the main contributors to GHG emissions in the Region. Therefore, it is a natural candidate to address with mitigation actions. Moreover, agriculture production competes with the area devoted to native forest, a sink for carbon in the atmosphere.

While the effects of climate change can endanger the standard of living of many poor communities that rely on subsistence agriculture, the relevance of agriculture for LAC countries goes beyond food security. Given the comparative advantage of many of the LAC, agriculture plays a key role for trade balance, and the trade and fiscal surplus that it creates is used as a source of resources to help the poor and to foster development, as well as maintain fiscal and macroeconomic stability.

Available aid funds are overwhelming oriented toward mitigation (see Keane et al., 2009). If those incentives were adopted, however, their expected final impact on production and yields, as well as on the trade balance, is uncertain. The resources available to cope with the Region's specific needs, such as droughts, erosion and endemic crop and animal diseases, remain highly limited.

[26] Nonetheless, the incentives of private sector actors and those of policymakers may not always be fully aligned due to the presence of market failures.

The relative scarcity of funds is not the only obstacle to adaptation. Potential projects have not been comprehensively catalogued, and the available lists respond more to individual country initiatives than to a systematic and comparative analysis. A systematic analysis of potential adaptation expenses to control erosion, to foster new varieties of crops, to secure irrigation, and to change practices and uses[27] could be a platform for establishing policies oriented to effective action. That analysis should include a comparison of effectiveness and costs of alternative adaptation measures.

This situation calls for research in several areas. First, it is necessary to identify what policies should be followed to adapt agricultural production to potential climate change shocks, including erosion, floods and new diseases. Second, it is necessary to identify low-cost mitigation actions that can be replicated in the Region. Third, the IDB should determine in which cases taking action is advisable rather than redundant; in some instances, such as the development of new crop varieties, the private sector could already be taking the initiative spontaneously. Research should additionally facilitate the diffusion of techniques already available and the identification of research opportunities with significant sectoral impact. Fourth, LAC agriculture projects should be cataloged and ranked to determine if the Bank could complement governments' actions in diffusing techniques that can help the poor, as well as provide incentives for research with significant sectoral impact. Fifth, research is needed on decentralization strategies for the diffusion of new crop varieties and production techniques.

The potential effects of developed countries' mitigation and compensatory policies, moreover, have not been sufficiently analyzed. While carbon prices or taxes imposed on transportation will have significant effects on agriculture supply, those effects have not been quantified for LAC in a setting of at least partial equilibrium agricultural models (like PEATSim, or similar). Similarly lacking is quantification of direct effects and of the modifications of supply and demand of big actors in world agricultural products markets. Individual countries and regions all over the world will respond to the incentives of climate change with modifications in their production, yields and area devoted to production, and those developments will almost certainly change agricultural prices. The net effect on prices for LAC crops and exports,

[27] Though there is still additional work necessary to determine the net contribution to GHG emissions in some cases, like biofuels. The net contribution depends also on the emissions of the intermediate inputs used in production.

however, are still uncertain. A survey of the available analytical treatments and computable models can be included in the working agenda for research.[28]

14. Forestation

Forestation and reforestation can provide inexpensive means of reducing GHG emissions and increasing GHG sequestration. Forest cut contributes between 20 and 50 percent of total GHG emissions. Available data indicate that emissions from land-use change (deforestation) accounted for almost a fifth of total world greenhouse gas emissions and almost a quarter of total world CO_2 emissions in 2000, and the current annual rates of tropical deforestation from Brazil and Indonesia alone would equal four-fifths of the emissions reductions gained from implementing the Kyoto Protocol in its first commitment period. As LAC's potential contribution in this area is relatively high, good management of forests could lead to a relaxation of the constraints imposed on other sectors such as energy and transportation, which are indispensable inputs for development, or at least reduce their costs.

The countries that account for the most of the Region's forests have shown their willingness to negotiate. However, it is not clear how to use the available funds; countries like Paraguay, with abundant native forests, have not been able to maximize the potential of the Clean Development Mechanism (CDM) nor is it clear so far how to decentralize action in an effective way. As many local communities base their livelihoods on the exploitation of wood and forests, securing the cooperation of local authorities and small communities will be indispensable in meeting forest management goals. Appropriate institutions and instruments have yet to be designed.

Why, though, is the case of forestry so special?

First of all, the role of forests in the environment goes beyond carbon sequestration. Forests help to sustain biodiversity and, as mentioned above, are very important in global precipitation and its distribution.

[28] As well as in agriculture, adaptation is highly likely to have an impact on fisheries management and/or the future employment of former fishermen. While this sector has considerable experience in adjusting to El Niño and La Niña effects, longer-term and less predictable changes are likely to require new analytical and policy approaches.

Secondly, even if cooperative solutions based on mitigation policies could be designed and enforced, forests remain vulnerable to potential calamities of climate change such as desertification and wildfires. Adaptation policies are thus needed as well.

Additionally, the protection of natural forests could be indirectly jeopardized by policies in other areas such as agriculture, mining and biofuels. The opportunity cost of opportunity of land used for forests is a key consideration. Alternative uses include agriculture (such as soybean production during the last decade in Argentina, Brazil and Paraguay) or mining (as in Brazil and Ecuador). Since forests are an asset, interest rates and the health of the macroeconomy can influence the effectiveness of the specific policies. High interest rates give an incentive to the accelerated depletion of natural assets.

Another particularly intense problem involving forests is enforcing policies in decentralized settings. The protection of forests requires direct monitoring in remote areas, in general managed by local interests of almost independent communities. Moreover, in many cases, natural forests overlap national boundaries, and the responsibility of individual countries is diffuse. In general, forest policy requires controlling asymmetries of information.

Current research outlines some of the issues involved in creating incentive compatibility conditions. Foremost among these is whether incentives such as the promotion of a sustainable exploitation and a market for sequestration will provide sufficient motivation for actors to preserve forests? While the preservation of forests is often considered a very cheap way to meet international goals, estimates of out-of-pocket expenses do not fully take transaction costs into account (ECLAC, 2009).

With these issues in mind, research should address opportunities for LAC to prevent deforestation and foster reforestation in a way consistent way with economic development. Also important is determining important to how to include local communities in those opportunities to make programs effective**.** Research should additionally focus on a case study to identify lessons for a variety of settings and countries.[29]

[29] Further research, as well as operations and project evaluation, will need to take into account the characteristics of different types of natural forests, as well as natural vs. managed forests. In tropical rain forests, for instance, nutrients are cycled primarily in the aboveground biomass and far less significantly through the soil. Soils of cleared rain forest areas are thus relatively nutrient-poor. This makes the restoration of the attendant ecosystem, or even a similar amount of biomass, a prolonged process. The insights of both physical and life scientists are likely to be needed.

15. Sustainable Cities

The most urbanized region in the developing world, Latin America is home to 55 of the world's 414 cities exceeding a million inhabitants, including eight cities of more than 5 million inhabitants. Some, such as the Mexico City, Sao Paulo and Buenos Aires metropolitan areas, are among the world's 15 largest cities.

Urbanization has played a significant and multifaceted role in the Region's development. On the one hand, poor urban infrastructure and lack of adequate housing have been persistent problems in most Latin American countries. On the other hand, urban growth episodes have been accompanied by benefits such as agglomeration economies, consolidation of labor pools and reduction of transport costs. The performance of the Region's cities has been mixed, as local governments have often been overwhelmed by urbanization dynamics.

Climate change presents a new challenge to urban management and economics. First, the boundary of emission accounting in the case of cities is under discussion. Thus, one can consider that it is not cities that produce GHGs but particular activities located there, such as manufacturing industries or power stations. For instance, Dobman and Satterthwaite (2005) estimate that cities produce between 30 and 41 percent of total GHG emissions. Second, cities in low and middle-income economies, such as those in LAC, have a lower impact on global warming as compared to large cities in developed economies. Instead, they will probably face higher risks from the impacts of climate change. Moreover, low-income populations, generally concentrated in risk-prone areas of these cities, will be the populations most affected by extreme weather events such as flooding, intensification of cyclones, and heat stress.

The climate change policy agenda for cities should therefore both mitigation and adaptation actions. Until now, policy developments have been uneven. While several Latin American initiatives in urban public transport and energy use are good examples of mitigation actions, investment in infrastructure for adaptation has been practically ignored. In the short run, an urgent focus on adaptation is needed to complement LAC efforts in social policies involving housing and domiciliary infrastructure for low-income populations.

Adaptation issues particularly in need of study include the following: i) the impact of floods on cities, ii) salinization of water sources, iii) health services[30] and the spread of disease in

[30] According to the IPCC "health services provide a buffer against the hazards of climate variability and change." Disease and disability reduce standards of living and productivity. The reciprocal causality is possible as well,

urban areas and iv) how to deal with extreme cases of the urban heat island effect. On the other hand, though mitigation may not represent a high priority for cities, resources available for mitigation investments could be used to improve the quality of life in cities; one important example is urban transportation. Research should lead to policy recommendations in these areas.[31]

16. IDB and Climate Change: The Analytical Agenda

Based on the discussion in the paper, we recommend the following agenda for future work, consisting of two analytical areas.

The **Operational Agenda** encompasses those analytical questions and issues that can have immediate operational consequences within the IDB. In the typology used by the Bank, the agenda corresponds to the categories "Policy and Capacity Development (PCD)" and "Advisory Services (AS)," but we do not make a distinction between these two in the present discussion.

Under the heading of **Research and Development Agenda** (which is also a category in the Bank's typology) we include issues that are relevant but require further study before they can have operational implications.

16.1 Operational Agenda

- **Guidelines for mitigation and adaptation project evaluation.** Several operational sectors have shown interest in acquiring a toolkit to complement technical environmental studies with sound economic principles for project evaluation. Among these sectors are transportation and logistics. Research

though, since poverty favors the spread of disease. Climate change shocks operate on both sides. On one side, frequent calamities (like droughts or floods) and the progressive increase of temperature (that helps the diffusion of vectors of transmission of diseases) affects the capacity of populations to reach minimum standards of living or food security. Even changes in patterns of flow in the Amazon basin seem to have effects on virus diffusion (see Kronik and Verner, 2010). On the other side, climate change can make communities poorer and then impact human health and productivity. Additionally, LAC countries are at risk in regard to the main factors (according to the IPCC) that increase the risk of health vulnerability: increase in total population and densification of urban areas. Adaptation expenses in health sectors can help to develop specific treatments that will not be available from general funding of the international community.

[31] Research, policymaking, operations and program evaluation may benefit by including assessments of locations' social infrastructure and capital. Metrics can presumably be proxied by household survey data and/or by opinion survey data, among other sources. Additional insights are likely to be available from research on the catastrophic natural experiments of the 2004 tsunami and the January 2010 earthquake in Haiti.

should help to develop this toolkit with specific applications for work to be conducted by IDB staff.

- **Identification of cost-effective adaptation actions.** Though we have identified adaptation as a key element of LAC's strategy of LAC for coping with climate change, this area has received little attention, and there is not yet a comprehensive survey of possible actions. Analysis should therefore identify the most cost-effective actions considering risk,[32] cost and social value. Resulting papers should be useful as a guide for the planning of interventions in LAC, including those to be promoted by the IDB.
- **Financial fragmentation and role of multilateral institutions.** At least 20 funds for climate change—frequently associated with mitigation actions—have been identified, each with its own rules and governance. Overlapping efforts might imply excessive competition for some sources of funds, and lack of access to others. Research should summarize available funds' characteristics and operating rules, and identify how the IDB can coordinate LAC efforts to make access easier and more effective.
- **Sustainable and efficient mechanisms of insurance.** Research in this area should identify supplementary actions that the IDB could undertake to complete the actions of governments and markets. Left alone, markets and even national governments may find themselves unable to provide sufficient levels of insurance. Since regional institutions have a role to play in pooling resources to face an indivisible risk, research should investigate the possibilities of developing a regional system under conditions of voluntary participation and compatibility of incentives.
- **Evaluation of trade and climate change using simulation models.** At present, several models that include climate change as an external shock to the economies are characterized by an abundance of results and methodologies, but that has not been accompanied by gains in transparency for policy analysis and decision-making. Research should survey the most important current

[32] The identification of risk will necessitate the elaboration of a technical paper examining in details the major impacts from climate change at relatively fine regional scales, with consideration of local topography, ecosystems, and current climate.

contributions, helping us to understand their main assumptions and the quality of data used. It should also make a contribution to the development of an independent transparent model that the IDB can use to simulate sectoral analysis (such as the impact of international prices on agricultural production in LAC) and also to estimate general equilibrium effects (like those stemming from international prices of commodities, and mobility of factors).

- **Certification and labeling.** There is a need to develop credible labeling in LAC, and do so at a low cost, in order to confront potential opportunistic evaluations used as trade barriers and to simplify access to markets abroad. It seems recommendable to assist the region in developing that instrument, whether it takes the form of a regional institution or some other arrangement. Research should seek to analyze the methodology and finance of the process.

16.2 Research and Development Agenda

- **Dynamics of growth and climate change: The LAC case.** The evaluation of the impact of climate change actions on growth has to be conducted in a macroeconomic integral model. Research in this area should seek to create a common platform for discussing how climate change policies and shocks can affect growth. Also, the dynamics of growth of LAC could change the relative relevance of mitigation vs. adaptation investments. For instance, in the future LAC could play a more important role in total emissions if its rate of emissions growth exceeds that of the rest of the world. The resulting model should permit calibration with different types of LAC economies and simulations of the interaction with other social and economic policies. The study should further include the assessment of several anticipatory scenarios to guide general policies, and do so in line with the lessons and parameters of this research agenda. The resulting model and research It should be transferred to IDB as part of its permanent research assets.
- **Labor market issues.** Two broad issues appear important in this area. One is the question of migrations. Historically, populations have sometimes migrated to cope with changing conditions. Although a population's mobility can

reduce the costs of climate change, there may also be undesirable side effects. For instance, populations may move to risk-prone urban areas simply because property prices there are reduced by shocks? The determinants of mobility need to be investigated analytically and empirically investigated, perhaps using historical as well as contemporary evidence. Of key importance is the role of information and subsidies in enhancing government's ability to help people cope with climate change by relocating to less affected areas.

The other question is how to implement taxes and environmental regulations in an economy where a large fraction of the population is informal. This would similarly require a study that combines an analytical model with empirical evidence; that study should not only be able to predict the effects of different ways to regulate the environment, but also to identify the most efficient course of action. In both cases, the studies undertaken should go beyond understanding the behavior of firms and markets. In particular, they should be designed in a way that facilitates a ranking of possible government interventions.

- **Regional trade agreements.** International community incentives, as well as the different endowments of countries, could create gains for countries that draw independently on special funds, some associated with transfer of technologies. The compatibility of those actions with RTAs is still in doubt and may require deeper analysis so as not to jeopardize trade relationships. Research in this area should contribute to establishing an initial platform for efficient discussion between partners of the main regional trade agreements.
- **Economic impact on LAC of new trade rules.** It is still not clear whether LAC should make an effort to modify its production processes and transportation costs, vis-à-vis the eventual sanctions, in the form of lower prices. The first action leaves rents and income within the Region; the second exports those rents to the rest of the world. The answer can be different depending on the comparative advantages of each country and on the pattern of specialization. The paper should make an assessment using some common and transparent platform of analysis, such as a computable general

- **Trade regulations.** Research in this area should address several issues of concern related to LAC exports and trade. Two are particularly salient: i) how to develop an independent labeling or certification for exports to prevent other countries from engaging in opportunistic behavior and ii) the harmonization of technology transfer agreements with WTO rules.
- **Sustainable cities**. The boundary of emission accounting in the case of cities is under discussion. One can consider that it is not cities that produce GHGs, but particular activities located there, such as manufacturing industries or power stations. Cities in low and middle-income economies, such as LACs, have a lower impact on global warming but will probably face higher risks from the impacts of climate change. Moreover, low-income populations, generally concentrated in risk-prone areas of cities, will be the most affected due to extreme weather events. Research should therefore go beyond mitigation to address investment in infrastructure for adaptation. Particularly important adaptation issues include the following: impact on cities of floods, salinization of water sources, diffusion of diseases in urban areas and how to deal with extreme cases of the urban heat island effect. Though mitigation is a lower priority for LAC cities, ample opportunities may arise to use resources available for mitigation investments in ways that improve urban quality of life in areas such as transportation, among others. Research in this area should provide specific recommendations.
- **Forestry.** Research should focus on opportunities for LAC to prevent deforestation and foster reforestation, identify successful experiences of sustainable economic exploitation and make recommendations on how to include local communities in those opportunities to make programs effective**.** Research should identify opportunities for obtaining resources from funds in ways that minimize LAC countries' search costs, and should assess LAC's possible gains in terms of carbon credits. Research should take advantage of experiences to date and derive relevant lessons.

- **Agriculture.** Research should focus on identifying what policies could be followed to adapt agricultural production to potential climate change shocks, including erosion, floods, wildfires and new diseases, and to establish in which cases IDB action is either advisable or redundant. In the latter regard, the private sector may already be taking the initiative spontaneously in areas such as developing new crop varieties. Research should help to assess the costs and benefits of policies and to identify efficient ways to diffuse techniques already available, as well as identify research opportunities with significant sectoral impact. Research in this area, as in forestry, should take advantage of experiences and draw lessons for LAC countries.
- **Adaptation Interventions.** Study what should be the priorities for interventions in this area, emphasizing cost-effectiveness and cost-benefit analysis, and taking into account the current uncertainty about the effects of climate changes and the possible complementarities of these interventions with the anti-poverty agenda of the IADB.

17. Conclusions

In this paper we address the issues identified as priorities for LAC countries with respect to climate change. While some elements of this research agenda can have an immediate impact on IDB operations, others require further data and analysis before they can be translated into action.

Though LAC countries can take advantage of incentives given by the international community to mitigation efforts, adaptation policies represent a more urgent priority. This is due to the fact that there are direct own gains from insurance and compensation, while mitigation reduces costs for the rest of the world. It is therefore plausible to believe that mitigation actions in the Region will only be undertaken in response to concrete economic incentives.

Adaptation includes several dimensions such as access to water, protection against human and agricultural diseases, needed help to the poor, and the development of infrastructure and cities. Some adaptation actions can be immediate and inexpensive, such as early alert systems, the development of guidelines for project evaluation, or new regulations for buildings and infrastructure. Other actions could be costly, however, and can be postponed until more is

known. Research and development addressing the Region's needs can provide a cost-effective way of learning.

Adaptation issues are also relevant for agriculture and cities. It is also advisable to design sustainable insurance mechanisms. Even some actions on international trade can be considered adaptation policies. The analysis of a regional labeling of products according to their GHG emissions could help to limit opportunistic actions on LAC exports. The harmonization of rules and regulations within regional trade agreements can help to preserve advances in trade liberalization.

There nonetheless remains a role for mitigation. In particular, mitigation should be undertaken when i) it helps to obtain financial resources that compensate for domestic actions and ii) it involves areas of particular interest to the international community such as natural forests.

Finally, since there remains much to learn in the area of climate change, the exercise undertaken in this paper should be refined and be repeated over time in order to take stock of new knowledge and to redefine priorities for research and action.

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