Chapter 5

Modeling the Economy-wide Impact of Climate Change

Key Messages

Economic modeling carried out under this study using the same model as in The Stern Review (2007), PAGE2002, confirms that Southeast Asia is more vulnerable to climate change than the world as a whole.

Without further mitigation or adaptation, the four countries—Indonesia, Philippines, Thailand, and Viet Nam—are projected to suffer a mean loss of 2.2% of gross domestic product (GDP) by 2100 on an annual basis, if market impact only (mainly related to agriculture and coastal zones) is considered, well above the world's 0.6%.

The mean impact could be dramatically worse, equivalent to 5.7% of GDP each year by 2100, if non-market impact (mainly related to health and ecosystems) is included; and 6.7% if catastrophic risks are also considered. These are far higher than the world's 2.2% and 2.6%, respectively.

Adaptation can help. At a cost of just 0.2% of GDP for investment in, for example, sea walls and drought- and heat-resistant crops, the four countries could avoid damage amounting to 1.9% of GDP by 2100, on an annual basis.

But adaptation alone is not sufficient. Concerted global action to mitigate GHG emissions is needed. Global stabilization of GHG concentrations at 450–550 ppm would significantly reduce the potential losses to the four countries.

A. Introduction

This chapter complements Chapter 4, which projected the physical impact of climate change at a sector level in the four countries (Indonesia, Philippines, Thailand, and Viet Nam). As stated, such projections are useful for understanding and anticipating the potential damage of global warming in the region and essential for designing future sector-specific adaptation measures. This chapter examines the economy-wide impact of climate change in monetary terms, expressed in losses as a portion of GDP. Estimates of potential losses from climate change in monetary terms allow aggregation of sector-specific impacts into a single measure. For this purpose, and to be consistent with the Stern Review (Stern 2007), this study used the PAGE2002 integrated assessment model.

B. Model and Scenario Assumptions

The Stern Review used the PAGE2002 model, as described in Hope (2006), to evaluate the long-term global impact of climate change. The model is stochastic and designed to encompass the uncertainties of the best available knowledge of climate science and economics. The coefficients and data ranges used are based on the Third Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC 2001a and IPCC 2001b). Two types of impact are considered: (i) market impact (on the agriculture sector and coastal zones); and (ii) non-market impact (on health and ecosystems). The possibility of future large-scale discontinuity is also incorporated to reflect the increased risk of climate catastrophes, such as the melting of the West Antarctic ice sheet. Greenhouse gas (GHG) emissions include CO_2 (energy-related and due to land use change and forestry), CH_4, and SF_6, while cooling from sulphate aerosols is also taken into account. Box 5.1 describes the PAGE2002 model in detail.

The model is applied using a global development path under the A2 scenario as developed by IPCC (2000). The A2 scenario describes a very diverse world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in a continuously increasing population at a rate higher than that in the A1 and B2 scenarios. Economic development is primarily regionally oriented, and per capita economic growth and technological change are more fragmented and slower than in the other scenarios (IPCC 2000). Emissions under A2 are relatively high—lower than A1FI which is the most pessimistic, but higher than B2, which is considered a medium-emission scenario in this study. Table 5.1 presents the key assumptions underlying the A2 scenario.

This study modified the original PAGE2002 model to allow for analysis of the four countries. In addition to the A2 scenario reflecting the business-as-usual (BAU) case, two global CO_2 stabilization scenarios, S450 and S550, are simulated to assess the avoided damage to the four countries resulting from global stabilization efforts. Moreover, an adaptation scenario is simulated for the four countries to estimate the costs and benefits of adaptation. Drawing upon a number of uncertain climate and impact parameters, the model generates probability distributions of results with a range of possible outcomes, based on 30,000 simulations using the Latin Hypercube sampling

Box 5.1. PAGE2002 Model

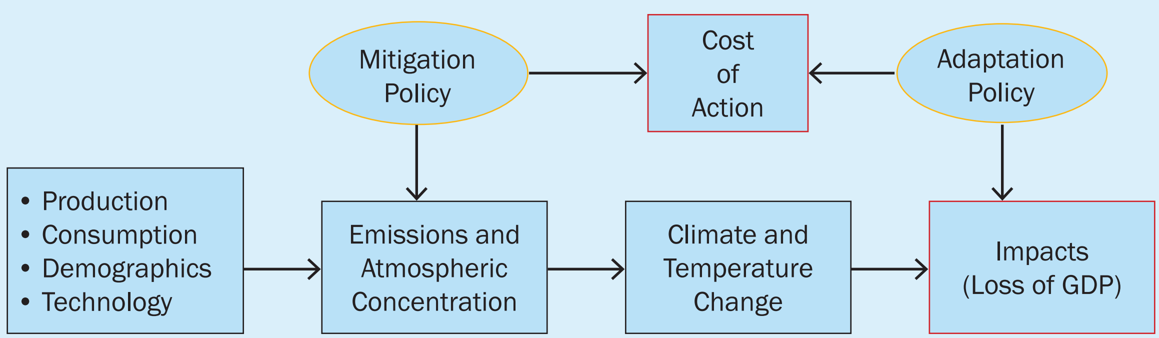
PAGE2002 is a top-down, global integrated assessment model developed at the University of Cambridge for climate policy evaluation and used by the Stern Review (2007) to provide estimates (in terms of gross domestic product loss) of the future economy-wide impact of climate change. The model divides the world into eight regions, but this study modifies and applies it to the four countries by explicitly treating them as separate regions.

It incorporates the most up-to-date knowledge on climate science and economics, in particular, how emissions, climate change, and impacts are interlinked (Box Figure 5.1). Model parameters were drawn from numerous studies documented in IPCC (2001a and 2001b), each having a probability distribution reflecting the uncertainties. The model estimates impacts through a damage function linking GDP loss with temperature rise. The impacts are driven mainly by three factors: (i) region-specific temperature rise, which is determined by radiative forcing from global GHG concentration (including CO_2 from energy-related and land-use change and forestry, CH_4, and SF_6) and regional sulphates; (ii) regional impact parameters which are a function of region-specific geographical characteristics; and (iii) region-specific adaptive capacity which is determined by the level of per capita income.

The possibility of future large-scale discontinuity is modeled through a linearly increasing probability of occurring as the global mean temperature rises above a threshold. By construction, the model is calibrated to the IPCC A2 BAU scenario in terms of anthropogenic GHG emissions, GDP, and population growth. It allows broad mitigation and adaptation policy evaluation.

To evaluate mitigation policy, the model estimates GDP loss due to temperature rise under the BAU scenario, and compares it with the GDP loss under alternative levels of global stabilization, namely, 450 ppm and 550 ppm. To evaluate adaptation policy, the model simulates the cost required for investment in measures that enhance a region's adaptive capacity, including the construction of sea walls and development of drought and heat resistant crops, in order to avoid a certain level (90%) of potential market impact without mitigation, and compare it with the benefit in terms of the avoided market impact. The cost parameters are obtained through bottom-up studies and are in line with UNFCCC (2007) estimates.

Box Figure 5.1. Chain of Impact and Policy Analysis of PAGE2002 Model



Source: Hope (2006), ADB study team.

method. The global results from the modified PAGE2002 model are in line with those reported in the Stern Review. It is important to note that there are currently great uncertainties associated with both the scientific and economic aspects of climate change. Therefore, the results in this study should be taken as insights into the direction and the orders of magnitude of the potential climate and policy impact, and not as precise forecasts of the future.

Table 5.1. Key Assumptions Underlying A2 Scenario

	Population (billion)	World GDP (trillion $, 1990)	Annual CO_2 Emissions ($GtCO_2$)	Annex-I to Non-Annex-I per Capita Income Ratio
2020	8.2	41	41.1	9.4
2050	11.3	82	63.8	6.6
2100	15.1	243	106.7	4.2

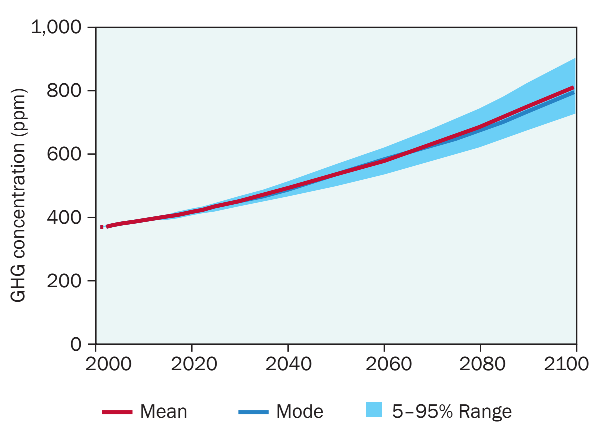
Note: The definition of Annex I is in Table 7.1.
Source: IPCC (2000).

C. Modeling Results

By 2100, global mean temperature would rise 3.4°C above its 2000 level, with a 5% chance it would rise beyond 5.5°C.

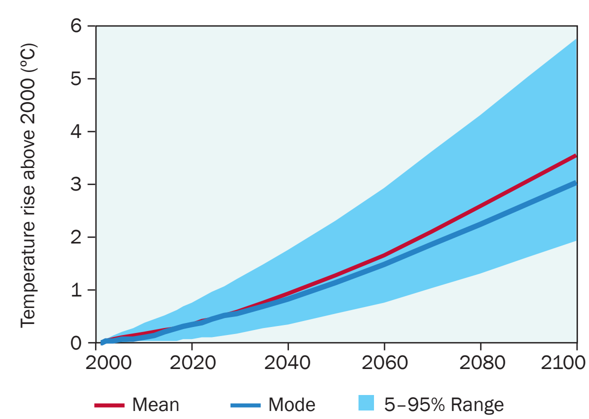
World production would increase by about 2% per annum on average under A2, with world population projected to double by 2100. As a result, annual GHG emissions would rise rapidly, increasing from 37 $GtCO_2$-eq in 2000 to 128 $GtCO_2$-eq by 2100. GHG concentration would likely rise beyond the safe level (450–500 ppm) by 2040 and to above 800 ppm by 2100 (Figure 5.1). Due to the complexity of the climate system, there is uncertainty about what the temperature level might be in the long run. But PAGE2002 projects that global mean temperature would rise by 3.4°C above the 2000 level by 2100 on average, with a 5% chance of increasing beyond 5.5°C by then (Figure 5.2).

Figure 5.1. Global GHG Concentration under A2 Scenario



Note: 'Mean' indicates the average outcome of the simulations, 'Mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is the shaded area.
Source: ADB study team.

Figure 5.2. Global Mean Temperature Rise under A2 Scenario

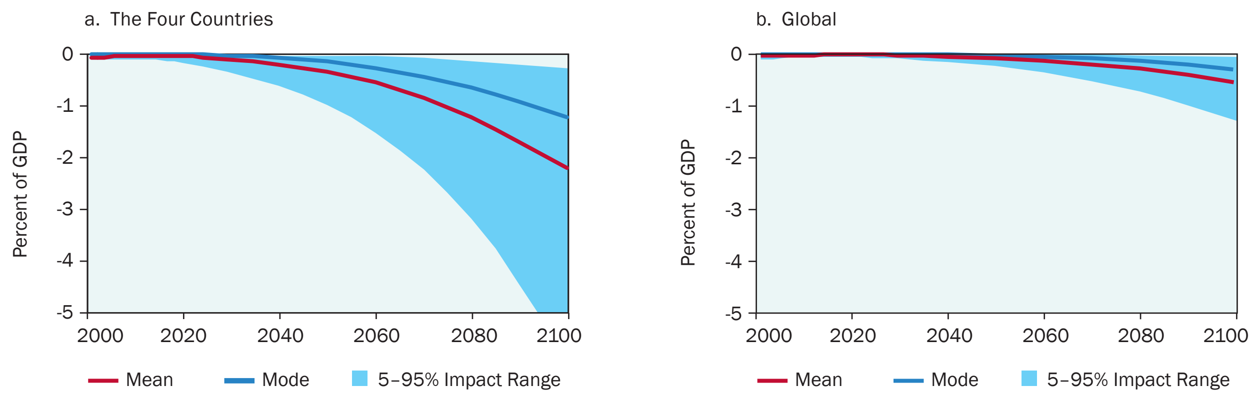


Note: 'Mean' indicates the average outcome of the simulations, 'Mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is the shaded area.
Source: ADB study team.

Without further mitigation and adaptation, the model projects a mean annual GDP loss of 0.6% by 2100 for the world as a whole, if considering market impact only. The losses increase dramatically when non-market impact and catastrophic risks are also considered.

As shown in Figure 5.3b considering market impact only, the mean annual global GDP loss is projected to reach 0.6% by 2100, with the mode

Figure 5.3. Loss in GDP (market impact only) under A2 Scenario



Note: 'Mean' indicates the average outcome of the simulations, 'Mode' indicates the most likely outcome, and the range of estimates from the 5th to the 95th percentile is the shaded area.
Source: ADB study team.

(or most likely) loss at 0.3%. The model estimates a 5% probability that the market GDP loss would reach 1.3% by 2100. But when potential non-market impact, such as on health and ecosystems, is considered, projected losses rise dramatically. When market, non-market impact, and catastrophic risks are accounted for, mean global loss reaches as high as 2.6% of global GDP annually (Figure 5.4b).

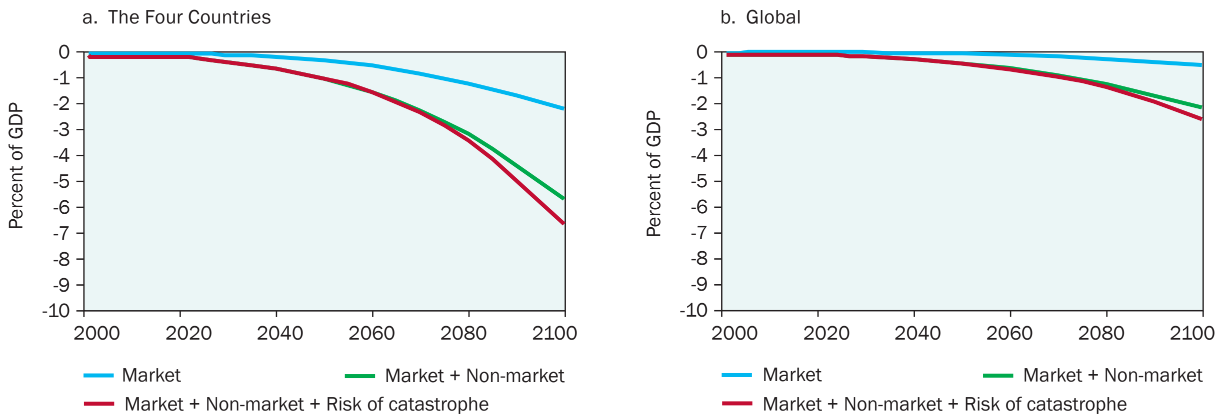
Southeast Asia is projected to suffer more from climate change than the global average.

For the four countries, without considering non-market impact and catastrophic risks, mean annual GDP loss is projected to reach 2.2% by 2100, with the mode at 1.2%, and a 5% chance that market loss would reach 5.8% (Figure 5.3a). The mean market impact in the four countries is three times the global mean market impact of 0.6% because, compared to the rest of the world, the four countries have relatively long coastlines, high population density in coastal areas, high dependence on agriculture and natural resources, relatively low adaptive capacity, and mostly tropical climates. This finding is consistent with those described elsewhere in this study. It is also worth noting that the distribution of the losses for the four countries is wider than for the global average, as indicated by the difference between the results at mean, mode, and 5% probability level.

The four countries could lose 6.7% of GDP each year by 2100 if non-market impact and catastrophic risks are also taken into account.

Climate change will also have non-market impact that would become highly significant over the longer term. The impact of climate change on ecosystems and health (non-market impact) in the four countries is likely to be greater than the impact on agriculture and coastal resources (market impact), with the gap growing larger over time as shown in Figure 5.4a. Under the BAU scenario, with no further mitigation and adaptation, combined mean GDP losses from market and non-market impact could reach 5.7% each year by 2100. If the chance of catastrophic events is also considered, they could reach 6.7% of GDP.

Figure 5.4. Mean Impact under A2 Scenario

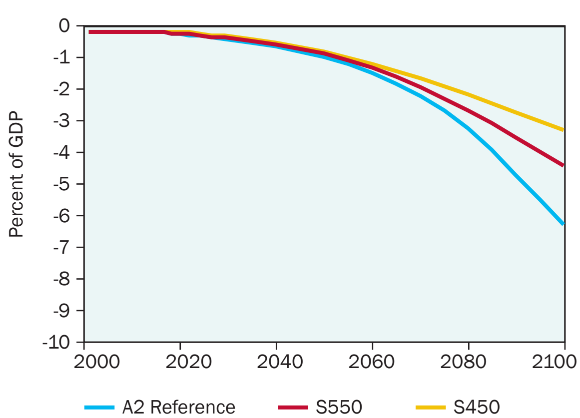


Source: ADB study team.

Stabilizing CO_2 concentrations between 450–550 ppm would significantly reduce the potential losses to the four countries.

The model shows that, with stabilization, the potential mean annual losses in GDP due to climate change are likely to be much lower—4.6% at S550 and 3.4% at S450 by 2100, compared with 6.7% under the BAU scenario, when considering market impact, non-market impact, and catastrophic risks combined. The savings of several percentage points of GDP suggest significant benefits from global mitigation for the four countries (Figure 5.5). Such benefits would be even greater beyond 2100. The results also show that the differences between the reference and the stabilization scenarios would become apparent only after 2050, partly because of the significant time lag between mitigation action and its impact on the climate system. Early global mitigation is urgently needed.

Figure 5.5. Mean Total Loss under Different Scenarios in the Four Countries



Note: Total loss includes market impact, non-market impact and catastrophic risks
Source: ADB study team.

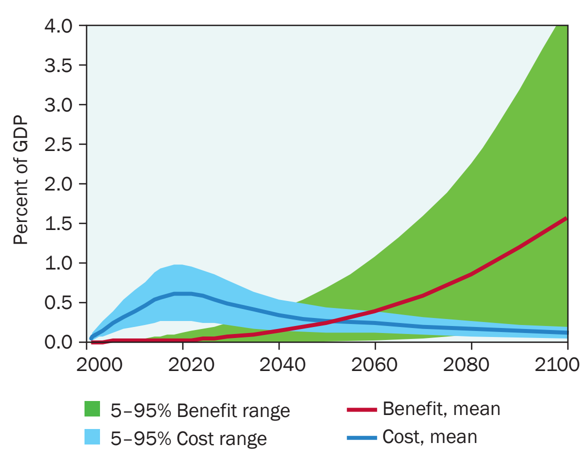
Adaptation can help reduce harmful climate change impact at a cost far lower than the ultimate benefit.

Understanding the costs and benefits of adaptation is important for planning. Existing adaptation cost estimates vary significantly from one study to another. UNFCCC (2007) estimates that the combined cost of adaptation in the agriculture, coastal zone, forestry, fisheries, health, infrastructure, and water supply sectors could reach $44 billion to $166 billion per year by 2030 for the whole world, and $28 billion to $67 billion for developing countries. UNDP (2007) projects adaptation cost for developing countries of around $86–109 billion per year by 2015. To meet developing countries' current adaptation needs, the World Bank (2006) estimates it would require investment in the range of $9–41 billion per year.

Studies of adaptation costs and benefits for Southeast Asia are still limited. The PAGE2002 model allows cost-benefit analysis of adaptation by comparing the cost associated with different levels of adaptation efforts with benefits from avoided climate change impact. The results show that, for the four countries, the cost of adaptation for the agriculture and coastal zones (mainly the construction of sea walls and development of drought- and heat-resistant crops) would be about $5 billion per year by 2020 on average, and that this investment is likely to pay off in the future. The annual benefit of avoided damage from climate change is likely to exceed the annual cost by 2060 (Figure 5.6). By 2100, benefits could reach 1.9% of GDP, compared to the cost at 0.2% of GDP.

Figure 5.6 also indicates the risks, with a 5% chance that the annual benefits from adaptation would not exceed the annual cost before 2080. Further, adaptation cannot entirely remove the projected damage of climate change, and thus must be complemented with global mitigation of CO_2, as analyzed above, in order to avoid the greater impact of future climate change. As mentioned, there are currently great uncertainties associated with the economic aspects of climate change. The results presented are meant to be illustrative and should only be taken to provide the orders of magnitude of the

Figure 5.6. Costs and Benefits of Adaptation



Note: 'Mean' indicates the average outcome of the simulations and the range of estimates from the 5th to the 95th percentile are the shaded areas.

Source: ADB study team.

potential policy impacts. But the modeling results indicate that interventions to adapt to and mitigate climate change present significant long-term economic benefits in avoided damage.

D. Conclusions

This chapter has shown that the global mean temperature would rise 3.4°C above the 2000 level by 2100 under the A2 scenario, with a 5% chance that temperature could rise beyond 5.5°C when climate uncertainties are considered. Under business as usual and no further mitigation and adaptation efforts, the PAGE2002 model projects a mean annual global GDP loss due to market impact alone of 0.6% each year by 2100. When non-market impact and catastrophic risks are also considered, annual global GDP loss could equal 2.6% of GDP by 2100. Moreover, Southeast Asia is likely to suffer more from climate change than the global average—about 2.2% loss of GDP on average annually by 2100, when considering market effects only, and 6.7% when non-market and catastrophic risks are also taken into account. Global stabilization at 450–550 ppm would significantly reduce the potential damage to the four countries. Based on the best available information, the benefits from adaptation are projected to outweigh the costs of implementing adaptation measures in the long term. However, adaptation alone is not sufficient. Global CO_2 mitigation will be needed to complement adaptation efforts in the four countries.

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