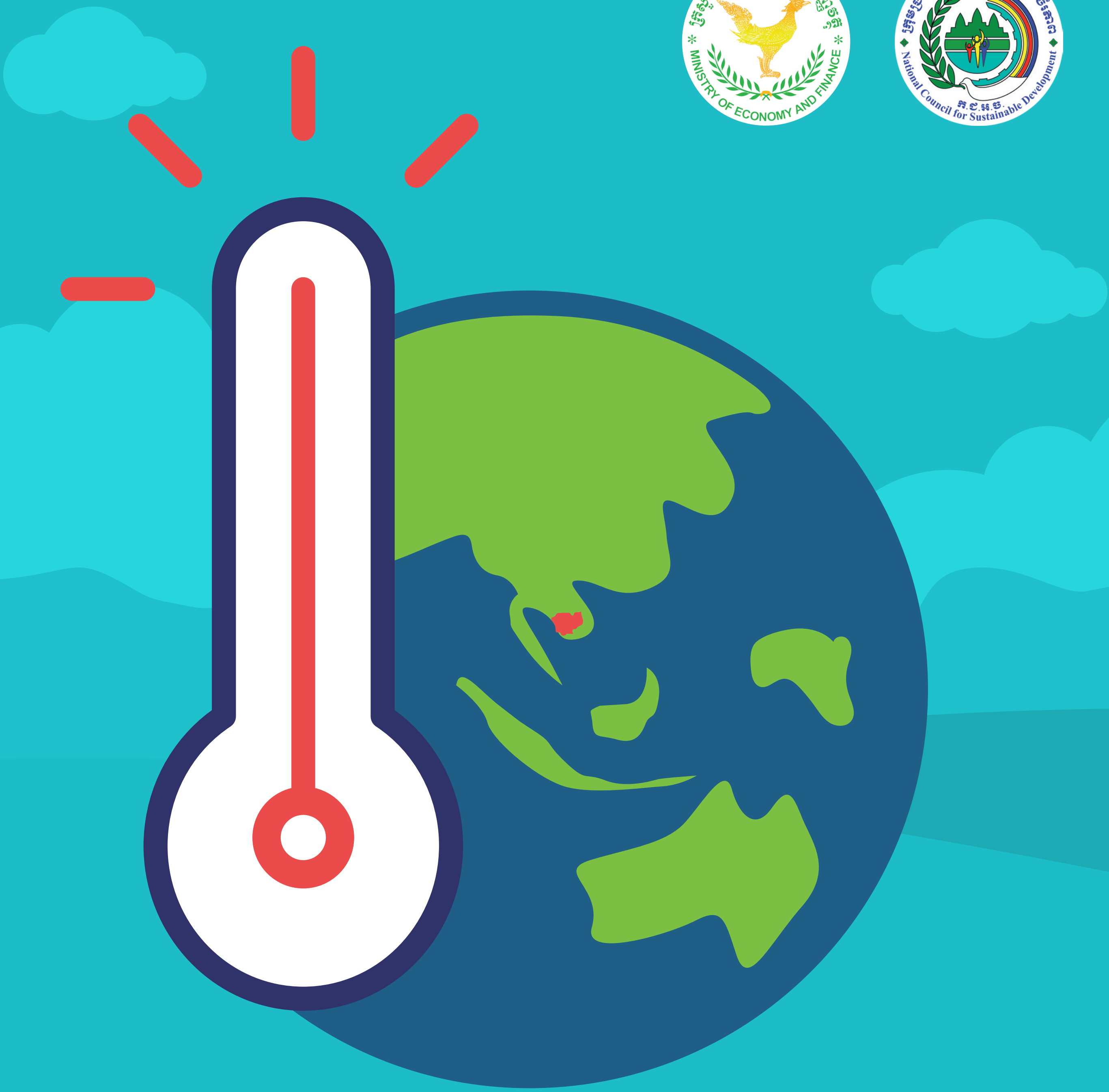
MINISTRY OF ECONOMY AND FINANCE

National Council for Sustainable Development



ADDRESSING CLIMATE CHANGE IMPACTS ON ECONOMIC GROWTH IN CAMBODIA

MAY 2018

CONTENTS

TABLES

FIGURES

ABBREVIATIONS

ABCR	Adaptation Benefit Cost Ratio
ABS	Adaptation Benefit Share
ADB	Asian Development Bank
AR4/5	IPCC Fourth/Fifth Assessment Report
ARCC	Adaptation and Resilience to CC Project
BAU	Business as Usual
BCR	Benefit Cost Ratio
CC	Climate Change
CC%	CC Relevance (see glossary)
CCAP	CC Action Plan
CCBA	CC Benefits Assessment (same as CCIA)
CCCA	Cambodia CC Alliance
CCCSP	Cambodia CC Strategic Plan
CCFF	CC Financing Framework
CCIA	CC Impact Assessment (same as CCBA)
CEGIM	Climate Economic Growth Impact Model
CPEIR	CC Public Expenditure & Institutional Review
CSES	Cambodia Socio-Economic Survey
DALY	Disability Adjusted Life Year
DBCR	Development Benefit Cost Ratio
DRFI	Disaster Risk Finance Initiative
EIC	Economics Institute of Cambodia
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation (ie investment in NA terminology)
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Green House Gas
GNI	Gross National Income
HIC	High Income Country
ICOR	Incremental Capital Output Ratio
IMF	International Monetary Fund
INDC	Indicative NDC
IPCC	Intergovernmental Panel on CC
KMR	Cambodian Riel

L&D	Loss and Damage
LMB	Lower Mekong Basin
M&E	Monitoring and Evaluation
MAFF	Ministry of Agriculture, Forestry and Fisheries
MBS	Mitigation Benefit Share
MEF	Ministry of Economy and Finance
MoE	Ministry of Environment
MoH	Ministry of Health
MOWRAM	Ministry of Water Resources and Meteorology
MPWT	Ministry of Public Works and Transport
MRD	Ministry of Rural Development
NA	National Accounts
NCDM	National Council for Disaster Management
NCSD	National Council for Sustainable Development
NDC	National Determined Contribution (to the Paris Agreement)
NPV	Net Present Value
NSDP	National Strategic Development Plan
O&M	Operation and Maintenance
PDNA	Post Disaster Needs Assessment
PFERNA	Post Flood Early Recovery Needs Assessment
RCP	Representative Concentration Pathways
RCRC	Ruby Coast Research Centre
RMSM	Revised Minimum Standard Model
SAM	Social Accounting Matrix
SNC	Second National Communication to the UNFCCC
SRES	IPCC Special Report on Emissions Scenarios
SREX	IPCC Special Report on Extreme Events
TFP	Total Factor Productivity
UMIC	Upper Middle Income Country
UNFCCC	UN Framework Convention on CC
USD	United States Dollar
Watsan	Water and Sanitation
WB	World Bank
WDI	World Development Indicators
WESS	World Economic and Social Survey

ACKNOWLEDGEMENT

This report and the corresponding CEGIM model was developed by the National Council for Sustainable Development (NCSD) and the Cambodia Climate Change Alliance (CCCA) programme, through continuous consultation with working group of Ministry of Economy and Finance (MEF) and other experienced officials of concerned ministries and development partners.

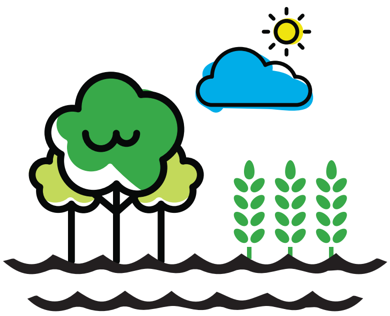
The consulting team was composed of Mr Kit Nicholson (Team Leader) and Mr Dourng Kakada, a local consultant. It benefitted from overall guidance of NCSD, including from H.E Tin Ponlok, Secretary General, Mr Sum Thy, Director of the Climate Change Department and Mr Ma Chan Sethea, Director of the Administration, Finance and Planning Department. The CCCA team included Mr Julien Chevillard, Trust Fund Administrator, and Mr Ung Soeun, Coordination Officer.

The working team at Macroeconomic and Fiscal Policy Department (MFPD) of General Department for Policy (GDP) of Ministry of Economy and Finance (MEF) included Mr. Lao Poliveth, Mr. Chantha Mengly and Mr. Than Yuthyea. It benefitted from overall guidance from H.E Ros Seilava, Under-Secretary of State of MEF, and supervision from Mr. Chheang Vanarith, Director of Macroeconomic and Fiscal Policy Department.

The authors are grateful to all contributors, interviewees and external reviewers for their inputs to strengthen the CEGIM model and to produce this resulting report. The views expressed in this report are those of the authors alone.

SUMMARY

> "Without climate change, CEGIM projects that real GDP will grow at an average of 6.9% per year from 2017 to 2050 […] Climate change reduces average GDP growth to 6.6% and absolute GDP by 0.4% in 2020, 2.5% in 2030 and 9.8% in 2050"



Introduction

Cambodia is highly vulnerable to climate change (CC). Rising temperatures are expected to reduce productivity in agriculture, fisheries and forests and to reduce labour productivity across most sectors. Changing rainfall patterns will lead to increased flooding, drought and storms which will also reduce resource productivity, especially in agriculture and fisheries, and increase damage from extreme events, affecting roads, water supply and other infrastructure. Rising sea levels will cause flooding and storm damage in coastal areas, affecting urban areas and natural resources.

The government response to CC includes a CC Strategic Plan (CCCSP), sectoral Climate Change Action Plans (CCAP), both in 2013, and the Nationally Determined Contribution (NDC) to the Paris Climate Agreement, in 2015. These define a range of priorities that cover most of the sectors affected by CC.

Cambodia has played a leading international role in responding to CC, being one of the first countries to conduct a Climate Public Expenditure and Institutional Review (CPEIR) and a CC Financing Framework (CCFF) and conducting an active programme to build capacity in CC Cost-Benefit Analysis. The Ministry of Economy and Finance (MEF) is now taking a further step by being the first country to develop and apply a Climate Economic Growth Impact Model (CEGIM), with support from the National Council for Sustainable Development (NCSD).

CC Impact

Loss and Damage (L&D) from CC can be grouped into three types of impact: a) loss of income, mostly from declining natural resource productivity (DY); b) reduction in labour productivity arising from heat stress (DL); and c) damage to assets (DK). There are many studies in Cambodia and South East Asia that consider these individually. CEGIM is calibrated by triangulating all these sources and then integrates them into a single analytical framework.

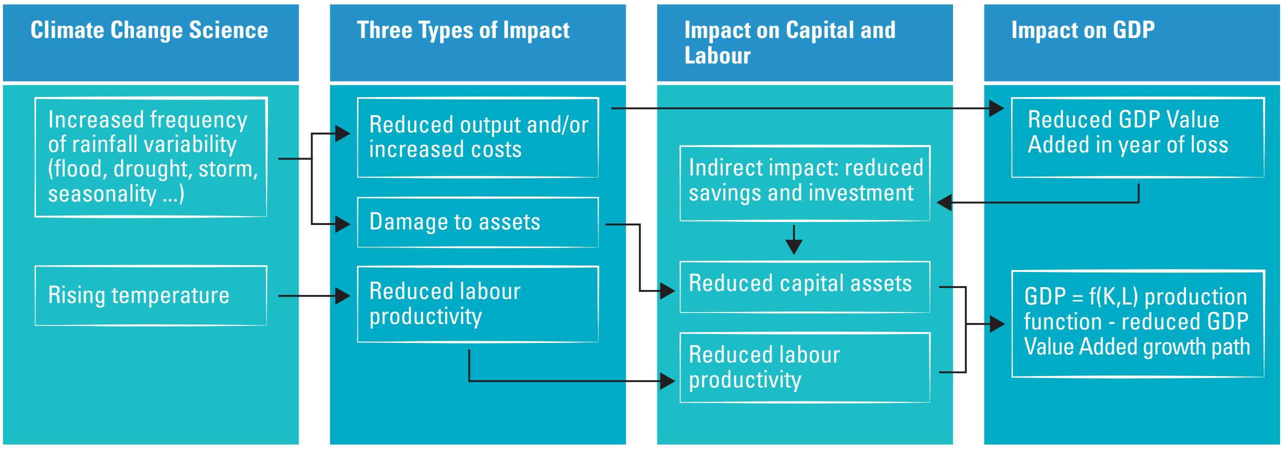
The Model

CEGIM is a simple economic model, built on a spreadsheet, that aims to distil the key features of the most widely used models of the economic impact of CC (eg PAGE and DICE). CEGIM is driven by a production function that determines GDP in any year from the stocks of capital (K) and labour (L) in that year. Capital is determined by investment and therefore, in theory, covers institutions and technology as well as infrastructure and equipment. Labour is based on employment data. A simple linear function (ie GDP = a + bK + cL) is preferred to a classic Cobb Douglas function and allows for changes in capital productivity (ie 'b') and labour productivity (ie 'c').

CEGIM accommodates the three types of direct L&D in the following ways.

- Loss of income reduces GDP in the year of loss, but has no direct effect on subsequent GDP.
- Heat stress and health effects reduce GDP through labour productivity (ie 'c').
- Damage to assets from extreme events and sea level rise reduces capital stocks (ie 'K').
- Any reduction in GDP indirectly reduces future GDP by reducing investment and, hence, K.

FIGURE 1 Overview of CEGIM



Evidence on Loss and Damage

Estimates of the values of the different types of L&D come from research, case studies, stakeholder consultation, physiological studies, damage assessments and evaluations. A wide range of evidence has been reviewed and best estimates have been based on a subjective triangulation of this evidence, giving greater weight to the sources considered most authoritative and most closely applicable to Cambodia. The table below summarises evidence sources.

TABLE 1 Sources of Data for the Three Types of CC Loss and Damage

Type of L&D	Source of Data
Loss of income	Research, case studies, stakeholder consultation, biophysical models
Labour productivity	Physiological studies in recent research on heat stress and labour productivity, done both internationally and in Cambodia
Damage to assets	Flood, drought and storm damage assessments, sea level rise modelling

CC Scenarios

The research evidence on L&D normally refers to CC scenarios as defined in the Intergovernmental Panel on CC (IPCC) Assessment Reports. CEGIM unifies these into low, mid and high scenarios (see Table 2). CEGIM uses estimates from the IPCC Special Report on Extreme Events (SREX) for increased frequency of extreme events, which are also used for other aspects of rainfall variability.

TABLE 2 CEGIM CC Scenarios

CEGIM Scenario	Low	Mid	High
IPCC Fourth Assessment Report (AR4) Scenario	B1	A1	A1B
IPCC Fifth Assessment Report (AR5) Scenario	RCP2.6	RCP4.5	RCP6.0

Calibration

Production functions are calibrated for each sector, based on 24 years of national accounts, from 1993 to 2016, which give data for GDP and investment. Capital stocks are based on the perpetual inventory method where the stock at the end of a year is based on the stock at the start minus depreciation plus investment. Depreciation for each sector is derived from Cambodian Cost Benefits Analysis (CBA) studies, triangulated with international evidence. Sectoral employment data is taken from the Economic Institute of Cambodia's 2009 Cambodia Economic Watch. The calibration produces surprisingly strong statistical results, although this needs to be explored with further work.

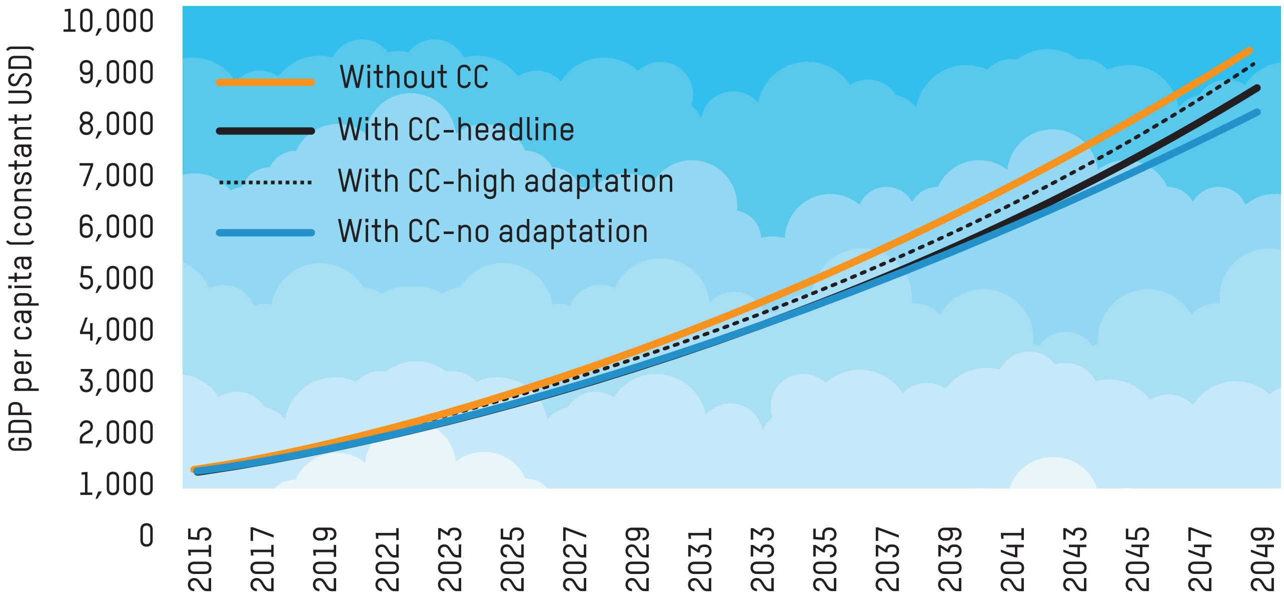
Headline Projections

Without CC, CEGIM projects that real GDP will grow at an average of 6.9% per year from 2017 to 2050, achieving Upper Middle Income Country (UMIC) status in 2035. With CC, the headline projections use the mid CC scenario and a mid-adaptation scenario that is equivalent to current levels of adaptation. CC reduces average GDP growth to 6.6% and absolute GDP by 0.4% in 2020, 2.5% in 2030 and 9.8% in 2050. UMIC status is delayed by one year. Figure 2 presents the GDP growth paths without CC and with CC, including 3 levels of adaptation.

Sensitivity analysis aims to consider the possible range in values for key parameters in the model, including the estimates of L&D, and the form of the production function. This suggests that the results in the headline scenario could be up to 40% lower or higher.

International studies using comparable but more detailed methods (eg the 2006 global Stern Review and a 2009 ADB study for SE Asia, both of which use the PAGE model) are ambiguous in the way they report their results, so direct comparison is difficult. However, assuming that these studies report the impact of CC on the NPV of GDP, the CEGIM results are several times higher than the results reported by these international studies. This is probably because: a) L&D is high in Cambodia, as a result of climate risks and the high importance of agriculture; and b) CEGIM includes recent evidence on the impact of heat stress on labour productivity, which accounts for over half the economic impact and was not included in the international studies.

FIGURE 2 Impact of CC on Economic Growth Paths – 3 Scenarios

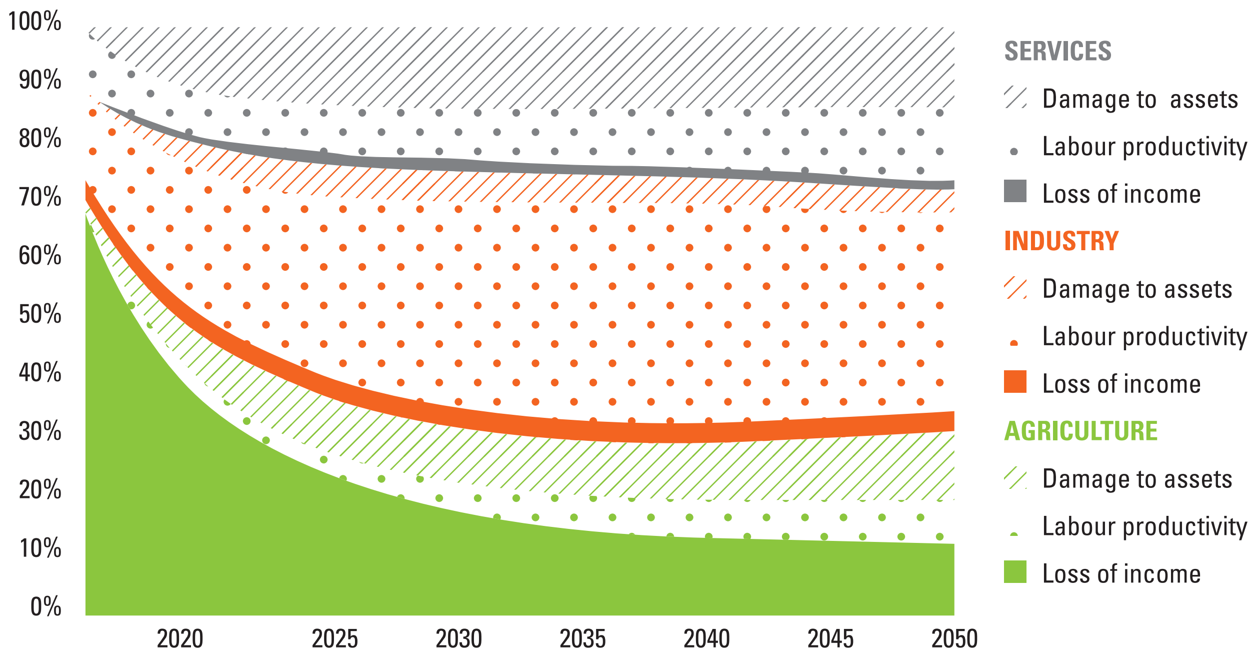


Sector and Type of Impact

The figure below shows how sectors are affected by CC and whether the impact comes through loss of income, labour productivity or damage to assets. In 2050, reduced labour productivity accounts for 57% of all L&D. It affects all sectors but is particularly high in manufacturing and construction. Loss of income accounts for 17% of all L&D and is concentrated in the four agricultural sectors. Damage to assets accounts for 26% of L&D and is spread across all sectors, being especially significant for service sectors, which are affected by damage to roads.

> "In 2050, reduced labour productivity accounts for 57% of all loss and damage. It affects all sectors but is particularly high in manufacturing and construction"

FIGURE 3 Economic Impact of CC by Sector and Type of Impact (% drop in absolute GDP 2050)



Policy Response

The CCCSP defines 64 strategies, of which 32 are directly focused on adaptation. The CCAPs define 115 actions, with 74 for adaptation, and the INDC defines 20 priorities, with 13 for adaptation. The strategies are comprehensive, except that there are no actions to reduce the impact of heat stress on labour productivity. The balance between planned expenditure on actions that respond to damage and actions that respond to loss of income is appropriate and roughly matches the level of L&D coming from each source.

Scale and Effectiveness of Adaptation

CEGIM estimates the scale of investment related to CC, using evidence from the CPEIR, for public investment, and a recent study in Cambodia on private CC investment. The effectiveness of adaptation is based on a portfolio of 29 case studies using Cost Benefit Analysis to estimate the total Benefit Cost Ratio (BCR), divided into Development BCR (which would happen without CC) and Adaptation BCR (which is the additional benefit when CC is taken into account and equates to the reduction in L&D). These case studies have been developed over a period of three years, in collaboration with line ministries, and are amongst the best sources of evidence on adaptation effectiveness anywhere in the world. This suggests that adaptation is currently reducing the impact of CC by about 13% and planned scales will increase this to 33% in 2050. This is similar to the conclusions of CCFF work in Cambodia and in other countries in South and South East Asia.

Findings and Recommendations

The CEGIM analysis should be treated with caution as the evidence base is still limited and it is the first time the CEGIM approach has been applied anywhere in the world. However, a number of indicative findings and recommendations (in bold italics) are possible.

- CC is likely to reduce absolute GDP in 2050 by nearly 10%, which is higher than suggested in previous modelling for South East Asia.
- Adaptation activities currently neglect the importance of heat stress on labour productivity. **More attention should be paid to activities such as: mechanisation; more labour efficient farming systems with flexible farm work scheduling; improved working practices on construction sites; better working conditions in factories (eg ventilation, drink breaks, more flexible schedules during heatwaves …); improved understanding of risks amongst workers and employers; improved forecasting and measurement of heatwaves; and planning to protect supply chains from heat stress. Most of the expenditure on this will come from the private sector, but government also has an important role.**
- Damage to infrastructure from extreme events is important and the share of total adaptation expenditure devoted related actions is appropriate. **It is important to ensure that actions to protect infrastructure from damage justify their cost effectiveness.**
- The evidence on the potential L&D to assets from sea level rise is not strong, but suggests that it could be more important than storm and flood damage. **If this evidence is correct, it would suggest that responding to sea level rise has been neglected.**
- Although it is often assumed that agriculture will continue to become less important, this trend may slow down because investment in agriculture is high. **Agriculture remains a critical area for adaptation policy, especially where issues of equity are concerned.**
- The current adaptation effort reduces L&D by about 13% and planned levels will increase this to 33% in 2050. **The adaptation effort could be doubled through a combination of: modest increases in spending (including more international finance); new policies to encourage private sector adaptation (especially on labour productivity); measures to incentivise improved cost effectiveness; and increased international funding.** This would reduce the adaptation gap to optimal levels, accepting that one third of L&D is unavoidable.

- Cambodia is making good progress in integrating CC into planning and budgeting through better understanding of the nature of risks and the performance of adaptation options and reference to CC in strategies and plans. **The CEGIM work should help to consolidate this work and provide evidence of the optimal balance between development and adaptation.**
- The evidence base for the CEGIM analysis is sufficient to draw useful conclusions but has weaknesses. **More evidence is needed to improve the way adaptation policy is analysed to assess its effectiveness in protecting macroeconomic performance. In particular, more work is required on comparing the timing of L&D threats and of adaptation benefits.**
- CEGIM aims to be transparent and easy to elaborate, but has already become quite complex. **This report includes suggestions for adding new features to CEGIM (eg on private investment or the distribution of CC impact) but this needs to be done carefully to avoid the model becoming too complex and inaccessible.**

01 Introduction

This report describes a Climate Economic Growth Impact Model (CEGIM) for Cambodia. The model is used to consider the full economic impact of climate change (CC) on Cambodia and the options for reducing that impact and maintaining growth targets. Chapter 2 describes the structure of the model and chapter 3 describes the evidence base and how this is used to calibrate the model. Chapter 4 describes the projections from the model and the extent to which GDP is reduced over the period to 2050. Chapter 5 presents conclusions and recommendations, including some conclusions on the balance of the policy response and suggestions for next steps on integrating CC into planning and budgeting. The report can be read in conjunction with a CEGIM Manual, which describes the structure and operation of the model in more detail.

1.1 Rationale

Cambodia is one of the countries most threatened by CC. The nature of these threats is well known and is described in the country's Second National Communication (SNC) and Nationally Determined Contribution (NDC) to the UNFCCC (MoE 2015, RGC 2015). Box 1 summarises the key assessments of vulnerability to CC.

Although the threats from CC are well known, the magnitude of the potential impact is still unclear. To improve understanding of the economic impact, three direct types of loss and damage (L&D) are defined, based on the way the types of L&D affect economic activity and the nature of the evidence on L&D (see chapter 3), plus one indirect type of L&D.

- Direct loss in economic activity from lower resource productivity and higher costs occurs largely because of floods, droughts, storms, irregular rainfall patterns, heat and sea levels.
- Damage to a country's infrastructure and assets occurs as a result of floods, storms and sea level rise and indirectly affects economic growth of sectors dependent on the assets.
- Heat stress affects labour productivity in most sectors, with especially high impact in arduous outdoor activities in the agriculture and construction sectors.
- Indirect effects occur when losses in one year lead to lower investment and, hence, lower capital assets, which affect future economic activity.

This classification also helps structure and prioritise the nature of the adaptation response: losses in output are reduced through measures that build resilience into production systems; damage to assets is reduced through the proofing of these assets; and adaptation to heat stress may involve changing production patterns and improved workplace conditions.

Chapter 2 describes an approach that integrates the three types of L&D into a single analysis of economic impact. Any assessment of the economic impact of CC must always be treated with caution for several reasons. Firstly, whilst the fact of CC is now almost universally accepted, the scale of CC at a global level is still uncertain, both because of the uncertainties about global emissions and because of uncertainties in climate science. Secondly, the nature and scale of CC at smaller scales is especially uncertain, especially in mountainous and maritime countries. Thirdly, the evidence about how CC will affect economic activity is still evolving and, whilst some areas are well researched (eg agriculture), others have only recently risen to prominence (eg heat and labour productivity) and do not yet have the wide body of evidence from which to triangulate reliable results. Finally, the way in which individual impacts join together to create total economic impact is still debated only by a relatively small group of economists.

BOX 1 Vulnerability

Cambodia's Climate Change Strategic Plan (CCCSP), published in 2013, reported that temperature in Cambodia is likely to rise by between 0.13 and 0.36 OC per decade. Rice yields are likely to decline by 10% for every 1 OC rise. Rainfall patterns are less clear, with some increase in average rainfall in hill areas in the wet season and a decrease in the dry season, which could harm coffee and rubber production. Sea level rise could reach 0.56m by 2090 under high CC scenarios, inundating 25,000 ha and increasing vulnerability to storms and affecting coastal towns and tourism. Coastal areas and the central plains are expected to become more vulnerable to flooding, affecting agriculture, fisheries, tourism, navigation and other services.

The Second National Communication (SNC) to the UN Framework Convention on CC (UNFCCC) was published in 2015 and provides a vulnerability assessment with further details. The assessment includes preparation of a Vulnerability Index which shows the geographical variation in vulnerability, including the effects of socio-economic status, infrastructure and population. The SNC also refers to analysis on flood and drought frequency contained in the National Adaptation Programme of Action (NAPA) produced in 2006. The SNC analysis showed that there is widespread local awareness of CC. Agriculture is most affected by CC, with 90% of losses from extreme events being related to crop harvest failure. The impact of CC on agriculture is closely connected with the impact of CC on water resources. Forest productivity is also likely to be reduced during the middle decades of the century, largely because of longer dry seasons, but may return to current levels by the end of the century. Coastal areas are vulnerable to increased flooding arising from sea level rise and to increased storm damage, affecting most economic activities. CC will also have a significant impact on human health, through increased threats from climate sensitive diseases and the effects of extreme events. Villagers are aware of the need for preparation, but there is limited capacity to adapt because of lack of financial resources.

Cambodia's Intended Nationally Determined Contribution (INDC) to the Paris Agreement was also published in 2015 and summarized the assessment in the SNC. Since 2015, there has been new work, both internationally and in Cambodia, on the impact of heat stress on labour productivity (Kjellstrom, Lemke et al. 2016). More details are provided in section A1.3 Annex 1.

Cambodia's vulnerability to CC is affected by the challenges of managing continuing rapid growth (World Bank 2017). This includes, in particular: a) the need to provide urban services that are resilient to floods and more unpredictable water supply, as well as providing relief from heat stress, where possible; b) the growing pressures on natural resources, including water, soil, fisheries and forestry; and c) the need to provide basic social services to a growing population.

1.2 Objectives and Scope

Objectives

The CEGIM Model aims to estimate the full economic impact of CC on Cambodia, taking account of both the direct effects on loss of production, reduced labour productivity and damage to assets and the indirect way in which this affects investment and growth. It also aims to illustrate how this can be used as a framework to help optimise adaptation policy.

In pursuing these key objectives, CEGIM aims to include the most recent sources of evidence, both internationally and for Cambodia, and it aims to use methods that are as simple and transparent as possible, whilst also being comparable with other international modelling on CC and economic growth.

Evidence Base

The modelling approach aims to provide numbers to policy makers, despite the uncertainties in the numbers. These results present the best available evidence and the level of uncertainty in the numbers is explored through the sensitivity analysis and the policy scenarios. Given the limited data available, and the uncertainties about much of the data, the results should be treated as tentative and not as precise projections.

Social Development and Environment

The version of CEGIM presented here focuses on economic impact. Some preliminary work is also done to consider whether CEGIM can add value to the debate on the impact of CC on income distribution (see section 4.6). More qualitative impacts on society and on the environment are not included. The scope of what is included in capital stocks is determined by what is included in investment in the national accounts, which does include public investment in institutions and in the environment. However, the assessment of L&D does not relate to the impact of CC on social development or on the environment. These are important issues, but CEGIM already represents a significant innovation in the practice of applied CC policy analysis in developing countries, so it seems sensible to limit the scope of this first version. Conceptually, it would be fairly straightforward to extend the analysis to cover other forms of CC impact, but this introduces issues of valuation which are not straightforward and are best managed as additional sensitivity analysis to an approach that is based on a scope of analysis that reflects current policy assessment.

Time Horizon

CEGIM is set up to run to 2050 because much of the data available on the L&D is based on moving instantaneously to a new climate scenario projected for mid-Century (ie either 2050 or, often 2045-2065). The projections for GDP in the outer years of this period should be treated with caution, not least because the assumptions about productivity are more speculative in outer years. The calibration was undertaken with 24 years of data, which might suggest that they should be considered less reliable beyond 2040. This includes the period in which Cambodia is projected to reach upper middle income status. ***However, although caution is required with the levels of GDP projected in the later years of the period, the projections for the relative impact of CC on GDP can be considered more reliable,*** since these are dependent primarily on the evidence on CC scenarios and L&D and are less affected by assumptions about factor productivity and the detailed specification of the production function.

1.3 Literature on CC and Economic Growth

This section aims to position CEGIM in the context of other models that explore the economic impact of CC as well as broader related macroeconomic modelling. CEGIM does not claim to be the most sophisticated model available and is based on a simple production function. It does, however, aim to distil the essence of the more sophisticated models and to present the analysis in a simple spreadsheet that is transparent and so easily adjusted for new sources of data or policy concerns. It can also be prepared rapidly and cheaply, in a few weeks, if reasonable data is available.

CC Economic Models

The foundations of CC economic modelling were laid in the late 1990s and early 2000s and include the development of the Policy Analysis for the Greenhouse Effect (PAGE) model (Hope 2011), the Dynamic Integrated Climate and Economy (DICE) model (Nordhaus and Boyer 2000) and the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model (Tol 2002). The models are neoclassical growth models in which growth is related to capital (financial and natural), labour and energy (both carbon and non-carbon). They both include CC damage functions and options to define mitigation and adaptation policy. These models have mostly been used to explore optimal global mitigation policy, and associated carbon pricing, rather than optimum national adaptation policy. A more recent elaboration of the DICE model has been influential in suggesting that the full economic impact of CC may be more severe than previously thought, if growth is treated more endogenously and the model considers the possibility that some L&D will be accelerate as CC becomes more severe (Dietz and Stern 2015). However, these results are mostly in the very long term (ie beyond 2100) and impact is still relatively modest in the period up to 2050.

The IPCC 2001 Third Assessment Report (AR3) reviewed the state of CC economic modelling, which suggested that global GDP would be 1-2% lower for a 2oC rise in temperature. The IPCC 2007 AR4 confirmed this evidence and extended the conclusion to be 1-5% for scenarios with a temperature change of 4oC and these estimates are repeated in AR5. These conclusions refer to the results of economic models that are based on neoclassical economic growth theory (see Box 2). The literature reports results in very ambiguous terms, but they appear mostly to report on the difference in the Net Present Value (NPV) of different growth paths.

The Stern Report

The Stern Report is perhaps the most widely influential international report on the economic impact of CC (Stern 2006). The report concluded that GDP would be 5% lower 'now and forever', but does not explain what the 5% figure refers to. Based on the PAGE model used in the report, it would appear that it refers to the reduction in Net Present Value (NPV) of GDP growth paths with and without CC. If the NPV of GDP growth paths to 2100 were 5% lower, then the absolute GDP in 2050 would be between 10% and 15% lower, depending on the discount rate used.

ADB Analysis in Asia

PAGE was also used in the ADB's 2009 SE Asia Review and 2014 S Asia Review (ADB 2009, Ahmed and Suphachalasai 2014). The ADB SE Asia study concluded that the region was *'projected to suffer a mean annual loss of 2.2% of GDP by 2100 on an annual basis, if market impact only … are considered … and 5.7% of GDP each year by 2100 if non market impact (mainly related to health and ecosystems) is included'* (ADB 2009). The interpretation of this conclusion is unclear. It is possible that the 5.7% refers to the absolute GDP in 2100. However, if that were the case, then the impact of CC would be so small as to be insignificant. Another possibility is that the report refers to the NPV of two GDP growth paths, one with and one without CC, which could be more significant, depending on the discount rate used in the model. But it would still be very small. The ADB study focused on Indonesia, Philippines, Thailand and Vietnam and so did not analyse the situation in Cambodia directly. It seems highly likely that the impact of CC on Cambodia, when expressed as a % of GDP, will be higher than the 4 countries considered in the ADB study because Cambodia is exposed to a greater level of risk and because it has a higher share of economic activity in the most vulnerable sectors. In addition, the ADB study was done in 2009, before much of the work on the significance of heat stress on labour productivity and before the evidence on storm and flood damage in Cambodia in 2009, 2011 and 2013.

Statistical Analysis

The above models include features that simulate the causal pathways by which changes in climate affect economic activity. An alternative approach is to use statistical methods to analyse the relationship between changes in GDP and variations in climate indicators across time and space, without identifying the causal pathways. The IMF 2017 World Economic Outlook described such an analysis and concluded that, in hot developing countries, a 1oC increase in temperature resulted in a 1.2% reduction in economic output[1] (IMF 2017). Both the simulation and statistical methods can involve sectoral details and there is significant overlap since the relationships in the causal pathways of simulation models can be calibrated with the same statistics of variations in output and climate, triangulated with evidence from biophysical models and case studies. Statistical models have the advantage of providing broad confidence in the scale of the potential impacts, although there are challenges in isolating the effects of other factors, like cultural and institutional issues, that may also be partly correlated with climate indicators but not affected by climate change. Simulation models have the advantage of being able to triangulate evidence from a wider range of sources and have more direct linkages with applies policy and project appraisal, but they may miss the many ways in which societies respond over time to adjust to initial changes.

CC Financing Frameworks (CCFFs)

Cambodia was the first country to undertake a CCFF that included projections of economic impact (MoE 2015). Similar work has now been done in Indonesia, Bangladesh[2], Afghanistan and in the Indian states of Kerala, Assam, Bihar and Chhattisgarh. These CCFFs have made the simple assumption that all L&D affects growth, which leads to much higher estimates of economic impact, with absolute GDP in 2050 with CC being between 30% and 50% lower than without CC. Concerns that this approach overstates the seriousness of CC have been influential in the development of the CEGIM approach.

World Bank RMSM and IMF Financial Programming

CEGIM draws on the experience of the World Bank and International Monetary Fund (MF) in macroeconomic analysis. In the 1970s and 1980s, the World Bank frequently used the Revised Minimum Standard Model (RMSM) to check the consistency of macroeconomic policy and assess the investment that would be required to meet growth targets (Addison 1989). The RMSM approach did not include a production function driving growth but instead used a macroeconomic framework that projected investment, including international borrowing, and checked the consistency of this with growth by looking at the trend in the implicit Incremental Capital Output Ratio (ICOR). Although the World Bank no longer uses RMSM on a regular basis, the IMF Financial Programming approach still uses a very similar approach to check the consistency of macroeconomic projections. CEGIM builds on this experience and includes a macroeconomic framework that determines investment, which then drives capital stocks and GDP.

[1] *The wording in the report is ambiguous and sometimes refers to a reduction in output and sometimes to a reduction in the growth rate, which are hugely different results.*

[2] *A slightly earlier CCFF was done in Bangladesh, but did not include projections of economic impact Ministry of Finance (2014). "Bangladesh Climate Fiscal Framework.." A brief revised CCFF was done for Bangladesh in 2017, but this has not been published or approved by government.*

Economic Growth Models

The CEGIM model is an economic growth model that is based on some of the earliest growth theory linking GDP to capital and labour (see Box 2) and adjusted to add the effects of CC. It therefore suffers from the strengths and limitations of all growth models. The reason why such models have been so popular for over a century is that they provide quantitative estimates of economic growth and how this is affected by investment and labour, which are linked to many of the most important public economic policies. They also provide a clear and flexible basis from which to expand and elaborate into new policy concerns by adding new features.

BOX 2 Growth Theory

Economic growth theory draws strongly on work in the first half of the 20th Century, which attempted to explain growth in terms of two factors of production, capital and labour.

The Harrod-Domar model was developed in the 1930s, following the pioneering work by Keynes. Growth is a function of capital stock, which is determined by the existing stock plus investment less depreciation. Investment is given by savings, which is given by assumed savings rate, which may be constant or change over time. Many subsequent growth models build on the Harrod-Domar foundation and provide further elaboration on the behaviour of investment, savings and the production function.

The Lewis Dual Sector model was developed in the 1950s and recognised that growth involved changes in economic structure, which the model illustrated by two sectors. The growth theory is similar to the Harrod-Domar model, but the model suggests that the increased productivity of labour and capital in modern sectors would lead to differential sectoral growth.

This early work on economic growth was elaborated by neoclassical theories, which suggest that actors pursue rational behaviour in search of optimum utility and that markets adjust to allow producers and consumers to achieve this optimum through adjustments to supply and demand. The following theories are the key building blocks of neoclassical growth theories and there have been a huge variety of more sophisticated models based on these foundations. The validity of each model is generally tested through statistical analysis.

The Solow-Swan model was developed in the 1950s and extends the Harrod-Domar model by using a more sophisticated relationship between capital and growth that incorporates changes in the productivity of both capital and labour. One of its most useful features was that the production function (ie linking output to capital and labour) could be calibrated by evidence from changes in productivity, which are therefore connected macro and micro economic theory and draw on the advances made in neoclassical theory.

The Ramsey-Cass-Koopmans model evolved between 1928 and the 1960s and was similar to other neoclassical models in being based on a production function that relates growth to the key factors of production. One of the key advances in this model was that the savings rate (and hence the investment rate) was based on a model of how households make trade-off decisions between current and future consumption.

Source: (Climate Scrutiny 2017)

Limitations of Growth Models. It is important to recognise the limitations of growth models, which have been widely criticised amongst economists. Limitations include the following.

- It should be clear that the results of the analysis are a simplification of reality and that the future will always be influenced by more complex processes than are captured by a model. To some extent, this limitation can be addressed by using sensitivity analysis to explore the range within which outcomes are likely to occur. They can also be addressed by expanding the scope of models to include valuation of other features of development, including social and environmental capital, for example. CEGIM would benefit from some of this extended valuation work (notably on environmental valuation) but this would complicate the analysis and could distract from the headline messages and undermine confidence in the analysis that is based on conventionally valued parameters.
- Some criticism of growth models goes deeper than this and suggests that the founding basis of neoclassical models (ie rational behaviour of individuals and achievement of an equilibrium between interests) do not apply and that modelled behaviour is so entirely misplaced that even the directions and orders of magnitude of projections are misleading.
- There are particular concerns about how neoclassical models deal with dramatic change, such as the collapse of institutions or the rapid rise of new economic systems. In CC work there is a particular concern about the validity of using economic models to explore the implications of catastrophic events. Most models deal with catastrophic change by treating it as just one of many future events, each of which has an estimated impact and probability. However, some scientists argue that presenting the average annual impact, weighted by probability, distracts policy makers from focusing on the most extreme, which may justify more policy attention than their weighted average impact would suggest.
- Finally, neoclassical growth theory was subjected to criticism about theoretical consistency, including the 'Cambridge Controversy' from 1950 to 1970, which pointed out theoretical problems associated with measuring capital value. These problems have parallels with the challenges in estimating capital assets in CEGIM using the perpetual inventory method. One strand of response to the Cambridge Controversy critique was that, although it may be correct, it does not undermine the value of neoclassical growth theory as an applied tool. This is similar to the finding that, although the starting capital stock estimates in CEGIM would seem to be important, they actually have little impact on the conclusions of the model, either for growth or for the impact of CC on growth.

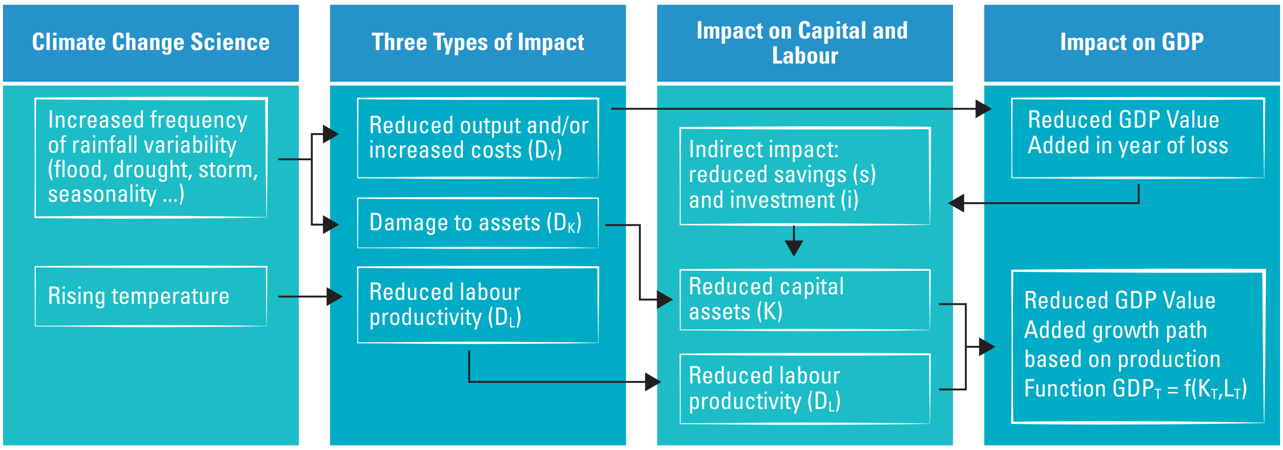
Despite these limitations, CEGIM aims to be a useful starting point for more informed analysis about how CC affects growth. It does not claim to replace the need for more detailed work on a range of related issues, such as institutional resilience (especially at a local level), social structures for adaptation and environmental processes. Provided the results are treated with caution, and with the knowledge that only part of the story is being told, they should provide a useful addition to the evidence on how CC affects Cambodia.

02
The CEGIM Model

2.1 Overview of the Model

Comparative Advantage of CEGIM. CEGIM aims to distil the essence of the more sophisticated models that are often used for modelling the impact of CC on economic growth. The innovation introduced by CEGIM is in the practical application of the concepts in a simple spreadsheet, relying only on the level of data typically available in developing countries. GDP in any one year is determined by a production function that depends on capital stocks and labour supply. This relationship between GDP, capital stocks and labour is ideally suited to analysing the impact of CC on economic growth because the three main types of CC impact each influence the three main variables: loss of income affects GDP directly; reduced labour productivity affects labour supply; and damage affects capital assets. In addition, there is an indirect effect as reductions in GDP result in reduced savings, investment and capital stocks. Figure 4 provides a diagrammatic overview of CEGIM.

FIGURE 4 Overview of CEGIM



The model uses high, mid and low CC scenarios which determine the level of impact on incomes, labour productivity and damage to assets.

Transparency and Flexibility. The most basic CEGIM, without sectoral details, requires one worksheet with less than 100 lines and can be viewed on a single screen. CEGIM does not claim to be more accurate and reliable than other models that explore the economic impact of CC, such as PAGE and DICE. However, it does aim to be transparent and easy to build and adjust and elaborate to country circumstances and policy interests. It aims to be useful for government officials and civil society organisations with limited time and data and without access to the sorts of economic modelling skills found in universities. The CEGIM Manual provides more details about the model.

2.2 The Structure of the Model

This section can be read in parallel with the CEGIM Manual, which provides more detail on the content and operation of the model.

CEGIM is based on the Distilled Growth Approach, which was developed by Climate Scrutiny to distil the essence of other CC economic models into an easily accessible, spreadsheet-based format that is adjusted to the data that is typically available in developing countries (Climate Scrutiny 2017). It has a similar structure to most of the models used internationally to assess the CC impact on growth, such as the PAGE model used by Stern and others, and the DICE and RICE models used by Nordhaus and others. The objective is to capture the most important ways in which CC affects growth in the most easily understood manner and not necessarily to pursue the most comprehensive analysis.

The CEGIM analysis uses the 15 sectors included in the national accounts. It is based on a production function and on projections for capital and labour, using the key relationships described in Table 3. Capital includes financial capital, as well as infrastructure and other physical assets. In theory, it could also include human, social and environmental capital, but this has not been done in order to keep the first step into CC growth modelling as clear as possible. L&D is divided into loss of income (DY0), reduced labour productivity (DL0) and damage to assets (DK0), each of which affects the production function and capital stock equation in different ways.

TABLE 3 Key Relationships in the CEGIM Model

Mathematical Form	Interpretation
$Y_0 = f(K_0, L_0, DL_0, DY_0)$	GDP (or Y_0) is determined by opening capital stocks (K_0), labour (L_0), reduced labour productivity (D_{L0}) and loss of income caused by CC (D_{Y0})
$K_1 = K_0(1\text{-}d) + iY_0 - D_{K0}$	Capital at year (K_1) end is capital at year start (K_0) minus depreciation (d) plus investment (iY) minus damage to assets (D_{K0})
$L_1 = L_0\, lg_0\, ls_0$	Labour (L_1) is determined last year's labour (L_0) times net population growth (lg) adjusted by differential growth rates for each sector (ls_0)

Production Function. The model makes projections of GDP based on the projections for capital stocks and labour. It is, therefore, impossible to 'control' GDP to achieve an expected growth rate and, if the projections are not as expected, then the only way to make adjustments is to revisit the evidence on key variables, such as the level of L&D, investment and depreciation rates. Two types of production function were explored:

Linear	$GDP = a + bK + (c\text{-}D_L)L - D_Y$
Cobb Douglas	$GDP = a * K\text{^}b * L\text{^}(c\text{-}D_L) - D_Y$

The first option involves calibrating the production function assuming that GDP has a linear relationship with capital and labour productivity. Assumptions are made about the change in capital and labour productivity for each sector to change over time, informed by past changes and any expected changes in future, driven by private enterprise and/or by public policy. The assumptions about future productivity provide some control over projections, which might be criticised for introducing scope for 'manipulation' of results. However, this criticism should not be valid if the feature is used cautiously, and the exogenous changes in productivity are based on evidence about past change and about likely future change.

The second option also defines capital and labour productivity based on past changes, but allows the relationship between GDP and productivity to be exponential[3]. It assumes that the GDP elasticity of capital and labour is constant (ie a 1% change in capital, or in labour, always results in the same % change in GDP). Economists prefer to use the Cobb Douglas production form because it allows for change in labour and capital productivity. However, for longer term projections, the Cobb Douglas production was found to produce unrealistic exponential growth. Further work is required to explore whether the rate of increase in capital and labour productivity that has been experienced through the last 23 years can be expected to continue through the next 34 years, up to 2050.

Capital

Capital is divided into private capital (pK), which is owned by the sector and is available exclusively to the sector, and public capital (gK), which is managed by government and benefits many sectors. Key types of private capital are field improvement, livestock, plantations, buildings and equipment. Public capital includes irrigation structures, roads, water and sanitation structures and flood and drainage structure. The GDP of each sector is based on the total capital stock for each sector including the private capital for the sector and a share of the public capital, which reflects the sector's share of total usage of the public capital.

For private capital stock, the change in stock is based on investment (iY) minus depreciation (dK0) minus the damage to private capital assets (DK), which is derived from damage from extreme events and from sea level rise. For public capital stock, the same principle applies, but the level of investment is determined through the macroeconomic framework (see below).

Labour

The supply of labour is based on population growth projections and on differential rates of growth of employment in each sector, which determine the sector shares of total employment. These sector employment growth rates are informed by past trends, although they can be over-ridden if there is evidence to expect future trends to differ from past trends. Labour productivity is reduced by the impact of CC on labour productivity (DL).

Macroeconomic Framework

CEGIM includes a basic macroeconomic framework. The main reason for including a macroframework is to ensure that projections of investment (and hence capital) are consistent with macroeconomic performance. In this analysis described in this report, both public and private investment are determined by the previous year's GDP growth, which could be done without the need for a macroframework. However, the macroframework allows consideration of other possible scenarios for both public and private investment. For example, for a given set of assumptions about revenue growth and recurrent expenditure, public investment could be set at levels that deliver a government deficit of a set target level (eg 3% of GDP). This would provide more rapid growth than assumed in the headline analysis.

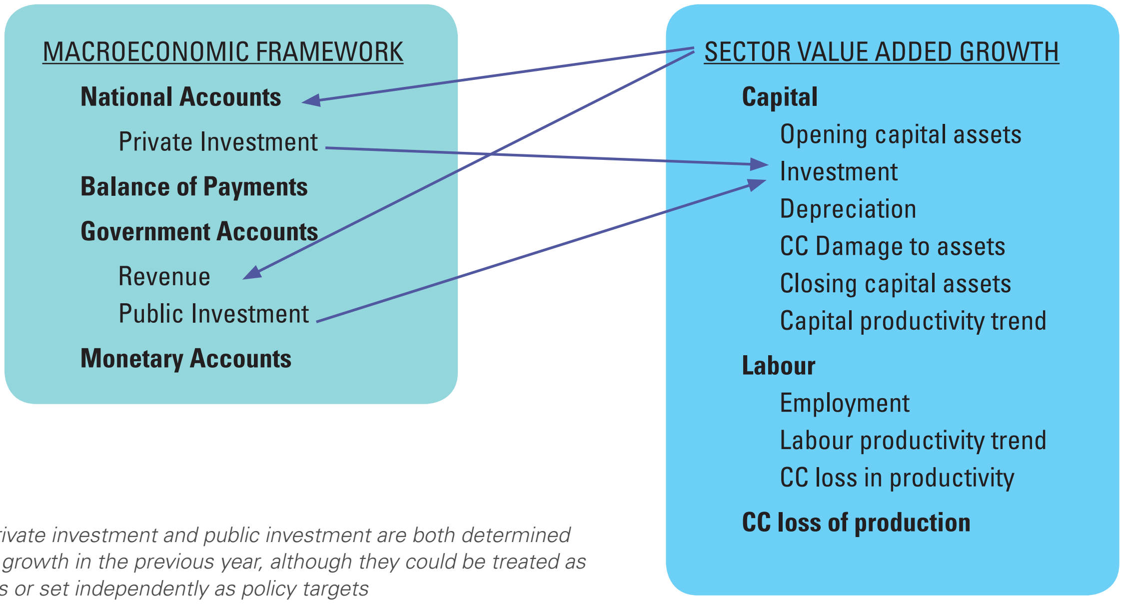
The macroframework also provides opportunities for conducting basic consistency checks on the reliability of the projections. The realism of assumptions about inflation can be checked by analysing trends in money supply, GDP and, hence, the velocity of money. The realism of assumptions about exchange rates can be checked by analysing trends in the balance of payments and net foreign assets. And the realism of implicit assumptions about investment effectiveness can be checked by comparing trends in growth and investment

[3] *When using a simple Cobb-Douglas function, the model assumes that total factor productivity (TFP) is always 1. This approach is taken to keep the model simple and because the quality and quantity of data are unlikely to be sufficient to get reliable estimates of TFP. Future versions of the model could assume gradually increasing TFP, perhaps calibrated by reference to other countries at a similar stage of development and good data.*

and, hence, the incremental capital output ratio. These basic consistency checks are a routine part of validating the realism of macroeconomic projections.

Figure 5 illustrates the relationships between the wider CEGIM model and the macroeconomic framework. In particular, it shows how the macroeconomic framework is used to estimate investment and, hence, capital assets.

FIGURE 5 CEGIM and the Macroframework



***

Note: private investment and public investment are both determined by GDP growth in the previous year, although they could be treated as residuals or set independently as policy targets

The macroeconomic framework follows the principles of the IMF Financial Programming model, as used in Article IV assessments (IMF 2007). GDP at factor cost (ie value added) is calculated from the sectoral analysis in the growth model. Subsidies, transfers and indirect taxes are taken from the government accounts in the framework. On the expenditure side of the national accounts, public consumption and investment are based on the government accounts and the trade balance is taken from balance of payments. Private consumption and investment are the residual in the national accounts, with the share devoted to investment being determined by the evidence on investment in the sectoral analysis.

The balance of payments projections are based on GDP projections, with exports linked to the growth of the export sectors and imports based on total GDP. Grants and the capital account are projected exogenously.

In the government account, tax and non-tax revenue are projected based on the appropriate elements of GDP (ie labour income for income tax, investment for profits, exports and imports for trade duties and total GDP for goods and services tax). Grants and financing are both projected exogenous to the model. Current expenditure is projected based on assumptions about gradually increasing share of GDP. Domestic financing is assumed to be limited at a set share of GDP and capital expenditure is the residual in the government account. Public investment is assumed to grow in line with GDP growth.

The monetary account is included to complete the financing framework but does not play an active role in the macroeconomic framework. Net foreign assets are based on the overall balance of payments and public domestic assets are taken from domestic financing in the government accounts. Overall money supply is determined by assumptions of the level of money supply as % of GDP, which allows for some increase in the velocity of money. Private domestic assets are the residual in the monetary account. These can be checked with projections of private investment to make sure that the two are roughly consistent.

2.3 Adaptation Policy

CEGIM focuses on understanding the full impact of CC in Cambodia. However, it also incorporates a simple analysis of the adaptation benefits that can be achieved through public expenditure on adaptation and through public policy that encourages increasing private expenditure on adaptation. This analysis uses the following steps.

1. Estimate the public and private investment that makes some contribution to CC
2. Estimate the Adaptation Benefit Cost Ratio (ABCR) of this expenditure, which determines the value of L&D avoided divided by the expenditure
3. Convert the total benefit figure into an annual stream of benefits

Adaptation Expenditure

Defining and measuring adaptation investment faces major challenges because adaptation is so closely integrated in routine development (see Box 3).

BOX 3 International Experience with Defining CC Expenditure

International work on defining CC expenditure has followed two main approaches. One approach focuses on the extent to which CC features in the objectives of a programme and this is the approach used by OECD and the Multilateral Development Banks (OECD 2011, MDBs 2015). Most CPEIRs have also used this approach and have developed a system for 4 levels of relevance and a CC relevance (CC%) (UNDP 2015). This measure reports on the extent to which CC has featured in the design of a programme.

The second approach considers the extent to which CC changes the net benefits of a programme. It estimates the Adaptation Benefit Share (ABS) which is defined as (B-A)/B, where A is the net benefits with current climate conditions and B is the net benefits when CC is taken into account. The net benefits may be estimated using qualitative assessment or quantitative analysis or a hybrid of the two. The approach has been used in most CCFF work and may apply to any expenditure, regardless of whether it is designed to respond to CC (UNDP 2017).

For example, an irrigation project costs USD 10m and delivers a benefit stream worth USD 20m under current climate conditions. CC increases maintenance costs by USD 2m because of increased floods and storms, but the benefits from irrigation increase by USD 6m because the irrigation protects farmers from rainfall variability, which becomes twice as frequent over the period. The BCR therefore increases from 2.0 to 2.4 and the ABS is 20%. The analysis is more complex for investments that include 'proofing' expenditure to reduce the L&D from CC. For example, a road costing USD 10m delivers a benefit stream worth USD 20m with current climate conditions and only USD 17m when CC is taken into account, because CC creates USD 3m of L&D, arising from increasingly frequent floods and storms. CC thus causes the BCR to fall from 2.0 to 1.7. Building CC proofing into the design adds USD 1m, but provides protection from USD 2m worth of L&D. The net adaptation benefits are therefore $1m and the ABS is 5.3% (ie 1m/19m).

The CC% reports on the extent to which CC has featured in the design of a programme whilst the ABS reports on the extent to which L&D is reduced. Thus, although both measures use a % score, they have complimentary roles and should not be confused. The CC% is often about three times higher than the ABS. For example, the majority of adaptation expenditure responds to increasing variability of rainfall (including flood and drought) and these programmes are typically given a CC% of 75% to 100%. However, assuming rainfall variability doubles the ABS will be only 33% without discounting and about 25% with discounting, depending on the discount rate.

Adaptation Benefit Cost Ratio (ABCR). The ABCR is calculated as total adaptation benefits divided by total costs. Both benefits and costs are usually discounted. Adaptation benefits are defined as the difference between the benefits with CC and without CC and equate to the level of L&D avoided. The ABCR is one of two parts of the total BCR, with the other being the Development Benefit Cost Ratio (DBCR), which estimates the value of benefits when CC is not taken into account. The Adaptation Benefit Share (ABS) is the ABCR divided by the BCR (see Box 3).

Annualised Benefit Streams

The objective of the policy analysis is to assess the extent to which different policy scenarios succeed in reducing the L&D arising from CC. This can be done by assessing the Net Present Value (NPV) of L&D over the period, as well as the NPV of the adaptation benefits. However, to do this, it is necessary to assess the proportion of the adaptation benefits that are felt during the period for which the L&D is estimated. Simply adding the NPV of all adaptation benefits and comparing the NPV of L&D would be misleading because many of the adaptation benefits from the CC expenditure during the period actually occur after the end of the period.

Instead of estimating the NPV over the period, CEGIM estimates the annualised benefit stream for adaptation expenditure. This is done by assuming that the routine development benefits are a stream of equal annual benefits whilst the adaptation benefits increase in a linear fashion over the period to 2050, as CC becomes more severe. This annualised approach has the advantage of potentially assisting with the prioritisation of expenditure over the period and assessing the extent to which some adaptation expenditure can safely be left for some years, until CC becomes more severe.

03
Calibration and Data Sources

3.1 CC Scenarios

Exposure to CC Risks. The starting point for estimating the impact of CC on economic growth is to understand the exposure of Cambodia to risks associated with CC. The evidence on L&D comes from studies that refer to a range of different CC scenarios, as follows.

- Loss of income is affected mainly by rainfall variability. CEGIM relies on the IPCC Special Report on Extreme Events (SREX) which estimates the expected increase in frequency of extreme events using three IPCC AR4 scenarios (B1, A1 and A1B), as defined in the IPCC Special Report on Emission Scenarios (SRES) (IPCC 2000, IPCC 2012). CEGIM assumes that all indicators of rainfall variability (ie floods, droughts, storms, unseasonable patterns …) are equally affected.
- The evidence on labour productivity is more recent and uses the IPCC AR5 CC scenarios (ie RCP2.6, RCP4.5, RCP6.0 and RCP8.5).
- Damage to assets is based on reports from past extreme events and global modelling on seas level rise. The National Committee on Disaster Management (NCDM) reports on the frequency and severity of extreme events (NCDM 2016). CEGIM assumes that these become more frequent in line with the SREX conclusions.

CEGIM defines three CC scenarios (high, mid and low). Table 4 maps the CEGIM scenarios to the IPCC CC scenarios used in the main sources of evidence.

TABLE 4 CEGIM CC Scenarios

CEGIM Scenario	Low	Mid	High
IPCC Fourth Assessment Report (AR4) Scenario	B1	A1	A1B
IPCC Fifth Assessment Report (AR5) Scenario	RCP2.6	RCP4.5	RCP6.0

3.2 Evidence on Loss and Damage

CEGIM draws on all sources of evidence on loss and damage (L&D) and to provide a subjective triangulation of this evidence, giving higher weight to those sources that have the strongest evidence based and that come from Cambodia or from countries similar to Cambodia. Annex 1 provides details about the evidence used to assess the potential loss and damage (L&D), including the exposure to risks and the impact on economic output, labour productivity and the damage to infrastructure.

Impact on Economic Output

There are a wide range of sources of evidence on the potential impact of CC on sectoral output. These mostly report on the effect of moving instantaneously from current climate conditions to the conditions in a future CC scenario, which often includes a mid-Century scenario. The assumptions used in CEGIM are derived from a subjective triangulation of this evidence, with higher confidence given to the most authoritative sources and those that related most directly to Cambodian conditions. Annex 1 provides more details and the table below summarises the evidence.

TABLE 5 Evidence on Loss of Output/Income in Key Sectors

Sector	Source	Impact of CC
Agriculture	Agriculture Public Expenditure Review (Mokoro 2010)	Increased annual losses by 2050 of 0.28% of GDP1
	USAID Mekong ARCC (USAID 2013)	Crop yields down by 3% to 6% by 2050
	ADB SE Asia study (ADB 2009)	Crop yields down by between 10% and 50% by 2100, depending on the CC scenario
	The Post Flood Early Recovery Needs Assessment (PFERNA) (RGC 2010, RGC 2014)	Losses of USD 152m in the 2013 flood and USD 56m in the 2009 typhoon.
	Cambodia CCFF (MoE 2015)	Losses of 1.14% of GDP by 20501
	Analysis of crop yield and area trends	Losses of up to 1.6% of GDP by 2050[1]
Livestock	USAID Mekong ARCC study (USAID 2013)	Pig productivity declines by 5% for every 1oC above 30oC
	Research in S and SE Asia (Younas, Ishaq et al. 2014)	Heat stress reduces productivity by nearly 10%
Fisheries	USAID Mekong ARCC study (USAID 2013)	Probably negative, but the scale of impact is not yet clear
Forestry	USAID Mekong ARCC study (USAID 2013)	Decline in productivity, but the scale of the decline is not clear
	ADB SE Asia study (ADB 2009)	Decline in productivity, could be serious
Energy	Cambodia CCFF (MoE 2015)	Losses in cooling and distribution to rise by 2% of the value of energy generation
Sea level rise	DARA Climate Monitor (DARA and Climate Vulnerability Forum 2010)	USD 250m in 2010, not taking into account possible increases to 2030

1 *The figures presented in %GDP refer to the losses when agriculture has the current share of GDP. These will fall as agricultures share of total GDP falls.*

Health and Labour Productivity

There are two main elements of impact on health: increased occurrence of diarrhoea and other climate sensitive diseases and increased heat stress and its effect on labour productivity. At present, the CEGIM analysis treats all of these impacts as a reduction in labour productivity but there may be some value in exploring how some health impacts reduce the supply of labour, rather than the productivity of labour, since this will have implications for the potential success of actions to improve labour productivity.

Climate sensitive diseases include most of the major water-borne diseases, of which the most important is diarrhoea, and diseases that are affected by heat, including cardiovascular and respiratory diseases. The CCFF reported WHO figures that suggest that the incidence of climate sensitive diseases could increase by 10% with CC, by 2050, which could be worth as much as 0.85% of GDP, assuming that Disability Adjusted Life Years are valued at three times GDP, which is the WHO guidelines. The ADB 2009 CC impact study suggested that CC could increase the burden from some climate sensitive diseases by as much as 18% over 30 years.

There has been some recent significant international progress in research into the possible impact of heat stress on labour productivity. The IPCC Fifth Assessment Report suggested that labour productivity could decline by more than 20% in the last half of the century, for sectors most affected (IPCC 2014). A recent global review by UNDP suggested that, with the worst case IPCC CC scenario (ie RCP8.5[4], with a 3.7oC rise), Cambodia would see an average reduction in productivity across all sectors of 6.54% by 2055 (UNDP 2016). The relationship between temperature and labour productivity is roughly linear so, if the Paris Agreement succeeds in achieving its best case objective of a 1.0oC rise, labour productivity would decline by 1.77% by 2050.

The same global evidence base was recently applied in more detail in Cambodia (Kjellstrom, Lemke et al. 2016), taking into account the share of employment in agriculture, industry and services, the way this share will change through the next century and the fact that the impact in outdoor activities is much higher than in indoor activities. The analysis suggested that overall loss of daylight work hours across the whole economy increases from current levels by 1.7% by 2050, using the RCP2.6 CC scenario, which is a relatively moderate CC scenario. In the high CC scenario (RCP6.0), labour productivity declines by more than 5.8% in sectors with heavy outdoor manual work where energy use is more than 400W/hour (eg agriculture and construction), by about 4.6% in other sectors with manual work (mainly in industry) and by 1.8% for services.

Damage to Infrastructure

CEGIM calibration of likely damage to assets from extreme events for each sector based on the following main source of evidence.

- The SNC estimates that damage from floods was $157m in 2000, $30m in 2001 and $12m in 2002, excluding loss of life and injury (MoE 2015).
- The Mekong River Commission flood damage analysis estimated the average damage to infrastructure in three districts between 2000 and 2007 was 2.5 $/person/year, suggesting a national total of about $35m, or 0.25% of GDP .
- The Post Flood Early Recovery Need Assessment Report (PFERNA) for the 2013 flood estimated the total cost of the 2013 floods as USD 356m, of which 202m was for loss (with 152m for agriculture), and 153m is for damage (with 80m for roads and 52m for water and irrigation (RGC 2014).

[4] *The IPCC's Fifth Assessment Report uses four main CC scenarios: RPC8.5, RCP6.0, RCP4.5 and RCP2.6. RCP8.5 is considered the worst case scenario, with little mitigation, and has an increase in global mean temperature of 2.0oC +/-30% by 2050. The RCP2.6 scenario reflects the best case target of the Paris Agreement and has a rise in temperature of 1.0 +/-60% by 2050. The other two scenarios are intermediate, with the change and range roughly proportional to the pathway concentration numbers. Projects from 2050 to 2100 are roughly linear.*

- The Post Disaster Needs Assessment for the Ketsana typhoon in 2009 as USD 132m, of which 74m was for losses (with 56m for agriculture and 11m for transport) and 58m for damage (with 15m for housing, 24mn for education and 14m for transport) (RGC 2010).
- The World Bank and GFDRR estimated average annual losses from natural disasters to be USD 74.2 million, or 0.7% of GDP, with floods accounting for 55%, droughts 28%, storms 4% and earthquakes 3% (World Bank, GFDRR et al. 2012).
- The Disaster Risk Finance Cambodia Country Diagnostic (DRFI) reported damage of USD 132m in the 2009, USD 625m in 2011 and USD 357m in 2014 (?). Further, the DRFI estimated average annual losses of USD 54n from floods, equivalent to about 0.7% of GDP (World Bank 2017).
- The NCDM analysis suggests that, in an average year, between 1000 and 2000 houses are lost from climate related disasters. This current level of damage is expected to double by 2050.

The L&D in the public sector is composed mainly of more rapid degradation of national and rural roads, irrigation, water and sanitation and flood protection infrastructure. Some L&D to public sector buildings will also happen. These losses can be reduced by higher spending on maintenance and adaptation. Assuming that the average annual damage to infrastructure over the last 10 years doubles by 2050 as a result of CC, the average annual damage to public infrastructure will be about 7% of the value of the capital assets. The government could divert resources to cover the increased damage, but this would then would divert public funds that could be expected to deliver BCRs of at least 2.0.

Damage from sea level rise is treated as damage to assets, although some of the L&D is likely to feature as lost income arising from soil salinity[5]. There is limited evidence on this and the estimate for likely damage is based on the DARA Climate Monitor figures for 2010 (DARA and Climate Vulnerability Forum 2010). The basis for the DARA estimate is not clear and further work is required to understand how the figure is derived, to ensure that it is correctly incorporated in CEGIM. This is important because the figure for damage arising from sea level rise accounts for over three quarters of all damage.

CC Scenarios and the Evolution of the Severity of CC. The primary source of evidence on loss of income and damage comes from the SREX report, which analyses three scenarios using the IPCC AR4 nomenclature for CC scenarios (B1, A1B and A1). The SREX analysis for SE Asia suggests average annual loss of income and damage would be 71% higher in 2050 than in 2016 with the B1 scenario, 94% higher with the A1B scenario and 84% higher with the A1 scenario. The RCRC evidence on labour productivity uses the AR5 nomenclature for CC Scenarios and provides graphs covering all four main scenarios (ie RCP2.5, RCP4.5, RCP6.0 and RCP8.5). The impact with the different scenarios is roughly proportional to the concentration. Thus, the RCRC conclusions are entered in the model using the RCP6.0 scenario and the severity factor is used to adjust these values if other scenarios are applied. Table 6 presents the severity factors for the scenarios and Annex 1 provides more detailed evidence on CC scenarios.

TABLE 6 CC Scenario and Severity Factors for L&D

	SREX CC Scenarios			RCRC Labour Productivity Scenarios			
Scenario	B1	A1	A1B	2.5	4.5	6.0	8.5
CC Severity Factor	71%	84%	94%	0.42	0.75	1.00	1.42

****Note: for AR4, the severity factor refers to the increase in losses/damages compared to recent average levels; for AR5, the primary evidence on labour productivity impact is recorded assuming RCP6.0 and the other CC scenarios are proportional to concentration*

5 *CEGIM chooses to account for soil degradation as loss of income, although it could equally be included as an asset, valued on the basis of lost income.*

The CC scenarios are used to provide an estimate of the impact of CC, if Cambodia moved instantaneously from current to 2050 climate. CEGIM assumes that the severity of each CC impact grows linearly between now and 2050. This is achieved through a 'CC Severity Index' in the model.

3.3 GDP Data

Data for GDP was taken from the national accounts provided by the NIS. The data goes back to 1993 and is presented in KMR, in both current and constant 2010 prices. The CEGIM analysis uses constant 2016 USD as the unit for the calibration and for the projections[6], first converting the KMR current prices into current USD using the prevailing exchange rate and then dividing the current USD values to constant values using a USD deflator based on World Bank data.

The analysis has used the 15 sectors identified in the national accounts, including 4 for agriculture, 4 for industry and 7 for services. A simpler version of CEGIM could have used only one service sector and would have reached a very similar result, because the impact of CC on all service sectors is assumed to be similar. However, the 15 sectors were retained in case evidence becomes available that that some of the sectors are more actively affected by CC.

The GDP of sectors refers specifically to the value of labour income and capital income (ie rent and profits) in the sector. Loss of assets in the sector does not constitute a direct reduction in GDP and only impacts through the effect it has on future value added. The sectoral implications of this are listed below.

- This concept is straightforward for the agriculture sectors and for mining and manufacturing, which includes textile manufacture.
- For electricity and water, GDP refers to labour income and any profits that may be made, if the services is provided by the private sector[7].
- For construction, the GDP refers specifically to the income and profits of builders. It does not refer to the capital assets created by the construction activity.
- Similarly, for real estate, the GDP does not refer to the value of buildings but to the income, rent and profits earned by companies that own the buildings. The real estate sector in the national accounts can include an estimate of 'imputed rent' paid by institutions that own their own buildings, but the extent to which this happens in Cambodia has not been explored. In any case, the GDP of the real estate sector should be roughly related to the capital value of buildings.
- The contribution to GDP of government services refers to the salaries paid to government officials and is mainly affected by labour productivity issues.
- The contribution of the transport and communications sector to GDP refers to the value of labour income, charges of use of equipment and profits in transport and communication enterprises.
- The value added from other services (ie trade, hotels/restaurants and other services) is straightforward and comprises labour and profits.

3.4 Capital Stock Data

Capital stock is estimated by the 'perpetual inventory' method, which assumes that the stock at the end of the year is the stock at the start of the year, plus investment less depreciation during the year. There has been some global work on this, which suggests that the capital coefficient (ie K/Y) for Cambodia is only about 1.1,

[6] *USD inflation has averaged 2.2% per year since 1993, compared with 5.7% for KMR.*

[7] *The GDP for the electricity and water sector is very low, compared to investment, and it seems possible that the valuation is based on subsidised costs, which do not include a return on capital.*

which is low (Berlemann and Wesselhöft 2017). These estimates are based on average depreciation rates taken from US data which are likely to overstate the depreciation rate because America's capital stock is likely to have a much higher share of assets that are high value and high depreciation.

The start level of capital stock for each sector is estimated by multiplying the first year investment by a factor which is common to all sectors. There is no evidence for what this factor should be, so it is selected to give the value which provides the most steady trend in K/Y over the period. Although this factor might seem to be critical in determining the results of the model, experiments with different factors suggests that it does not, in fact, have a significant impact.

Annex 2 gives more detail about the investment figures used in the CEGIM analysis, broken down into public investment, bank lending, foreign direct investment and reinvestment by households and enterprises. The figures used in CEGIM are higher than in the national accounts, reflecting the NIS concerns that GFCF has been underestimated in the national accounts, at least since 2010.

Depreciation

The estimates for depreciation are important for the model because they determine the part of investment that is devoted to depreciation and, hence, the extent to which additional investment is available to increase capital assets and so deliver growth. The World Bank WDI database includes figures for depreciation from 1995, which suggests that, as a national average it has risen from 4.4% to 10.2%, which is a faster rise than in most other countries in the region. There are no official Cambodian statistics for depreciation by sector or type of asset and the estimate is therefore made on the basis of case studies and the stakeholder consultation. The estimates for sectoral asset shares and depreciation are presented in the table below.

TABLE 7 Depreciation of Private Assets by Type of Asset and Sector

	Private Assets						
	Earth-works	Live stock	Plant-ations	Equip-ment	Buil-dings	Total	Depreci-ation
Dependency of Sectors on Assets							
Crops	90%			10%	10%	17%	8.1%
Livestock		100%			1%	5%	9.7%
Fisheries	10%			1%	1%	2%	7.9%
Forestry			100%		1%	2%	5.0%
Mining				4%	1%	2%	13.8%
Manufacturing				22%	10%	14%	12.9%
Electricity & water				5%	1%	3%	14.0%
Construction				15%	5%	9%	13.4%
Trade				10%	10%	8%	11.4%
Hotels & restaurants				5%	5%	4%	11.4%
Transport & comm.				15%	5%	9%	13.4%
Financial sector				3%	2%	2%	12.3%
Government services				5%	38%	14%	6.9%
Real estate				1%	5%	2%	6.5%
Other services				5%	5%	4%	11.4%
Total	100%	100%	100%	100%	100%	100%	10.6%
Depreciation	5.0%	10.0%	5.0%	15.0%	5.0%		
Share of total assets	10.0%	5.0%	2.0%	53.0%	30.0%		

It is possible to validate these estimates for depreciation by comparison with accounting standards in different countries. For example, Ernst and Young provide a review of the depreciation rates allowable for tax purposes (Ernst and Young 2016). This covers 26 countries of which the most similar to Cambodia are India, China and Malaysia. Depreciation rates are as follows: plant, machinery and equipment – China 10%, India 15%, Malaysia 14%-20%; cars – 25%, 15% and 20% respectively; land and buildings – 5%, 10%, 3%-10%; roads – n/a, n/a, 6%; agricultural equipment – n/a, various, 20%-40%. These figures provide some indication although it should be born in mind that some standard accounting rates will be higher than actual depreciation where governments have tax incentive policies to encourage investment. More detailed rates are provided in government documents, such as the Indian government document on depreciation allowances which includes rates of: 1.95% for dams, weirs and canals; 3.4% for reinforced concrete structure in hydraulic works; and 3.02% for roads (GoI 2007).

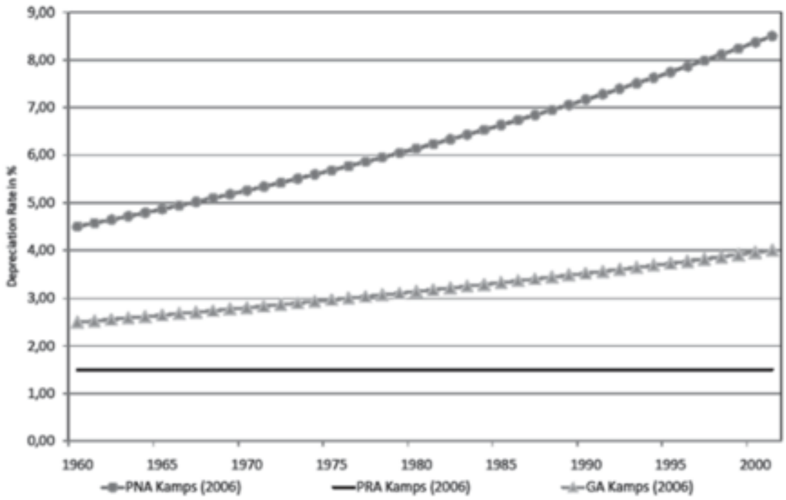
For government assets, there are no official sources and the evidence comes mainly from previous case studies and discussions with stakeholders. Expenditure on maintenance provides one good proxy for depreciation since the objective for maintenance is to avoid substantial depreciation. However, public expenditure on maintenance is often below ideal levels in most government departments and so this will probably underestimate actual depreciation. Another source of evidence for public assets is the cost benefit analysis undertaken for many case studies for CCFF work, which has drawn on the experience of engineers in government departments. This suggests that depreciation is 5.0% for irrigation assets, 4.2% for roads, 2.6% for water and sanitation and 3.3% for drainage and flood protection.

TABLE 8 Depreciation of Public Assets by Ministry and Sector

	Private Assets									
	Social	MAFF crops	MAFF other	Rural MOW-RAM	Rural MRD	MIME	MPWT tran-sport	MPWT wat-san	Power	Other
PIP (% sector totals)										
Crops	0%	90%	0%	85%	23%		10%			16%
Livestock	0%		25%		5%		1%			3%
Fisheries	0%	10%	50%	5%	5%		1%			6%
Forestry	0%		25%		5%		2%			2%
Mining	0%						2%			2%
Manufacturing	0%				20%	25%	15%		33%	17%
Electricity & water	0%			5%	1%	75%	1%	50%	33%	1%
Construction	0%				5%		10%	50%	33%	12%
Trade	5%				20%		25%			10%
Hotels & restaurants	5%				5%		3%			5%
Transport & comm.	5%				5%		10%			9%
Financial sector	2%						2%			2%
Government services	75%			5%	5%		5%			1%
Real estate	5%				1%		5%			7%
Other services	2%						8%			8%
Total	100%	100%	100%	100%		100%	100%	100%	100%	100%
Share ot Total (from PIP)	32%	4%	4%	9%	3%	4%	12%	4%	4%	24%
Depreciation	5.0%	5.0%	5.0%	5.0%	4.2%	5.0%	4.2%	5.3%	5.0%	5.0%

The above depreciation estimates are based on the current circumstances in Cambodia. There is good international evidence that, as development takes place, the complexity of capital assets rises and average depreciation rates rise. This is one of the reasons why, in the long term, growth rates slow with development. CEGIM assumes that depreciation rates change in line with the international evidence presented in the figure below, which reports on private non-residential assets (PNA), private residential assets (PRA) and government assets (GA). The figures are taken from data for the United States from 1950 to 2011 and so are used only to indicate the annual rate of change in depreciation, rather than the absolute levels of depreciation. The World Bank World Development Indicators includes data for Cambodia on the consumption of fixed assets (ie depreciation) which suggests that between 1995 and 2015, the national average rate of depreciation increased by 1.77 times between 1995 and 2105, which is lightly higher than the Kamps data used to calibrate CEGIM.

FIGURE 6 Change in Depreciation



Source: (Kamps 2006)

3.5 Labour Data

The labour available to each sector is based on the employment in the sector. This is expressed as numbers of people, although it could also be an index (eg with 2016 employment set as 1), provided that the unit used for calibration is also the unit used in projections.

Total employment from 1993 to 2016 is taken from the ILO adjusted estimates available in the WB WDI database[8]. The sectoral shares of employment come from Economics Institute of Cambodia data in the 2009 Cambodia Economic Watch report (EIC 2009), which provides a breakdown into sectors similar to those used in the national accounts[9] for 1990, 2000 and the years 2006 to 2010. For the years between 1990 and 2000, and between 2000 and 2006, employment is interpolated assuming linear growth change. From 2010 to 2016, employment by sector is extrapolated by assuming that the actual growth rate from 2006 to 2010 is maintained until 2016. This results in significantly different figures to those provided in the Cambodia Socio-economic Survey (CSES) for 2014, which suggests that agricultural employment is much lower and that both industry and services are significantly higher (NIS 2014).

[8] *The WDI database also includes figures for employment broken down into agriculture, industry and services. These have not been used in the CEGIM calibration, but could be added to add further triangulation and validation to the data from the Cambodia Economic Watch data used.*

[9] *There are four sectors not covered in the EIC report: mining, financial services, real estate and 'other'. These are estimated by assuming that the GDP/employment for these sectors is the same as the average for all the services sectors that are covered in the EIC report.*

The projections in labour supply from 2017 to 2050 are taken from the World Bank Population and Estimates database, which shows that the growth rate falls from 1.58% in 2016 to 0.54% in 2050. Employment growth rates for each sector are set exogenously, based mainly on evidence from trends since 1993. No account is taken of possible changes in age structure of the population.

3.6 The Production Function

The production function is derived from statistical analysis of GDP, capital and labour over 23 years from 1993 to 2016[10], using Ordinary Least Squares regression. The results from calibrating the model are as follows:

$$Y = -1631 + 0.48K + 0.54L \quad \text{(linear)}$$
$$Y = 0.915 * K^{0.89} * L^{0.08} \quad \text{(Cobb Douglas)}$$[11]

The primary focus of the CEGIM analysis is to explore the impact of CC on GDP, rather than to provide accurate projections of absolute GDP. The marginal impact of CC should be considered more accurate than the projections of GDP growth rate themselves, since it is well known that there are many factors other than capital and labour that contribute to economic growth, especially in the longer term.

National and Sectoral Level Analysis

The production function can be calibrated and operated at two levels.

- At a national level, there is only one production function for the combined value added of all sectors. This national level analysis requires an estimate of national average data for all key variables (eg the three types of L&D, depreciation and trends in employment and in factor productivity). The evidence for this data is mostly specific to sectors and so estimates are needed of sectoral GDP, in order to make an average annual estimate, weighted by sectoral GDP. Thus, the national level analysis has exactly the same logical structure as the sectoral level analysis and requires the same evidence base, but has the advantage of being computationally less detailed. It also has the advantage of providing more stable results because sectoral level analysis is vulnerable to poor quality data on some sectors leading to exponentially unstable results, especially when trying to use the Cobb-Douglas production function for longer term projections.
- At a sectoral level, the model is specified with production functions for each sector and the national results are obtained by adding the results for all sectors. This level has the advantage of allowing changes in the sectoral composition of the economy to be taken into account, as the production functions and CC L&D for each sector feed through into differential sectoral growth rates.

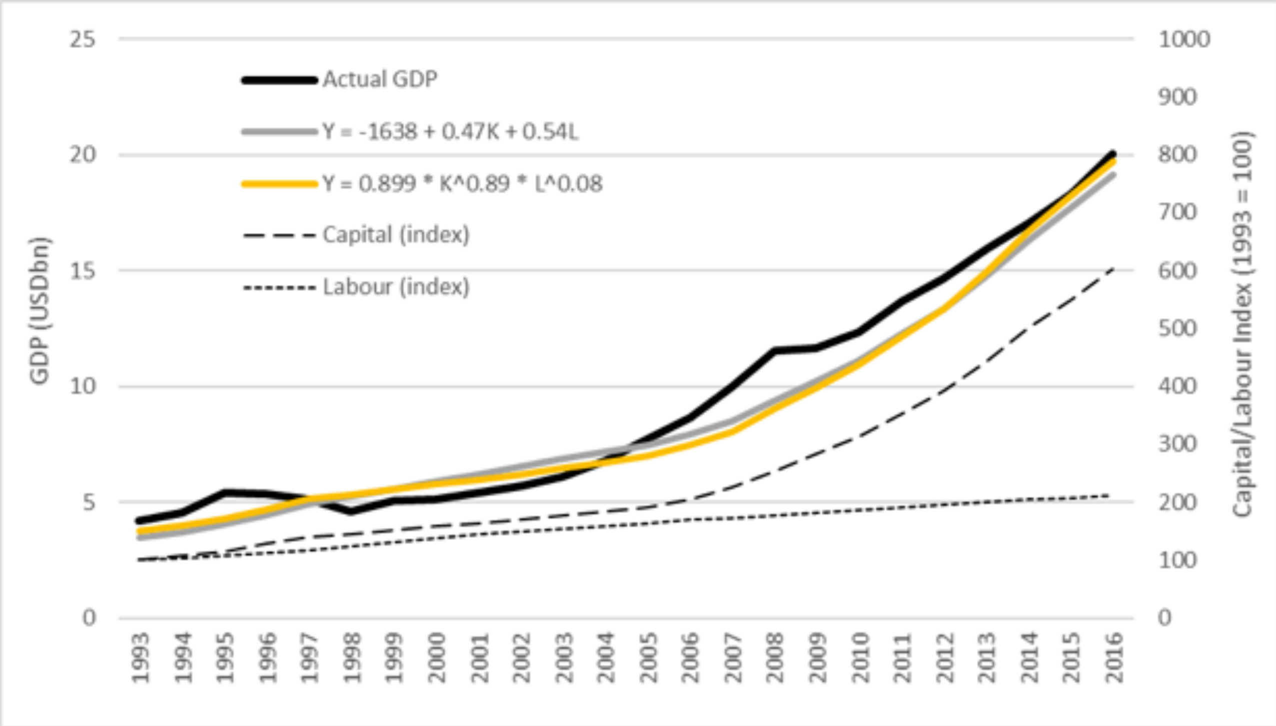
Figure 7 presents the actual and modelled GDP using the two different types of production function. Whilst the figure shows that both production functions provide a reasonably accurate estimate of GDP during the period. The correlation coefficients are very high[12], which is not surprising because capital stock is partly determined by investment which is related to GDP and because labour and GDP both grow exponentially. This strong statistical relationship gives some confidence in the analysis of the implications for GDP of the marginal impact of CC on capital and labour.

[10] *Although the analysis covers 23 years, some of the early year data is less useful because it is 'projected backwards', based on assumptions of constant sector shares.*

[11] *The coefficients for the Cobb Douglas production function suggest a high capital elasticity and low labour elasticity, compared to most norms. The reasons for this would require further analysis, but are not explored since the Cobb-Douglas function is not used in the headline CEGIM.*

[12] *The R^2 for aggregate GDP is 97.2% for the linear production function and 94.9% for the Cobb-Douglas. For both types of production function, the R2 for individual sector production functions are over 95% for most sectors, but are between 80% and 95% for most agriculture sectors, except for forestry, which is lower. The standard error of the coefficients in the aggregate GDP liner production function is 10% of the coefficient for capital assets and 41% of the coefficient for labour, suggesting greater confidence in the capital coefficient than the labour coefficient. The standard errors for coefficients in the sector production functions are mostly between 10% and 40% but there are several sectors with higher standard errors for one coefficient (usually labour), including agriculture, liestock, forestry, construction and trade.*

FIGURE 7 Actual and Modelled GDP



The production functions provide estimates for 2016 that are slightly different to the actual results, which creates an unrealistic step (up or down) if moving from actual 2016 to modelled 2017 results. To avoid this, an 'first year adjustment factor' is calculated, so that the modelled 2017 results reflect the growth projected in the modelled results for 2016 and 2017. In practice, this adjustment factor is estimated as the difference between actual and modelled GDP for 2016 and it is added or subtracted to all years from 2017 onwards.

Factor Productivity

The model includes a feature that allows for an improvement in capital and labour productivity. For both capital and labour productivity, the trends are based on analysis of the trends over the past 23 years. CEGIM includes a feature to allow the starting level of the rate of increase in productivity to have a one-off uplift to reflect priorities in government policy to improve productivity. However, is is not used in the headline scenario. It is assumed that this rate of improvement will gradually decline over the period, as Cambodia catches up with normal international levels and options for improvement are more limited.

Currency Units

The coefficients are estimated from the data on GDP and on capital assets and labour. It does not matter which units and currencies are used for GDP, capital and labour, but it is essential that exactly the same units are used in the calibration as are used for projections. In the CEGIM analysis, the units are: constant USD in 2016 prices for GDP and for capital assets and number of people employed for labour.

3.7 Existing Adaptation Policy and Expenditure

Adaptation Investment

For public CC investment[13], CEGIM assumes that all public investment in agriculture, irrigation, roads, utilities and manufacturing makes some contribution to adaptation. In 2016, these sectors accounted for 68% of total public investment. CEGIM allows for this proportion to be changed as part of a sensitivity analysis, but it remains constant for the three main scenarios.

For private CC investment, Cambodia is one of the few developing countries in the world that has some evidence, through a recent review coordinated by NCSD (NCSD 2016). This review suggested that private CC investment, weighted by a score of CC relevance (CC%) (see Box 3), averaged USD 61.4m per year over the 3 years to 2015. Of this total, 68.9% was in the agriculture sector, 11.0% in energy, 10.5% through households expenditure, 6.8% in manufacturing and 2.2% in transportation, with smaller amounts in waste/water, construction and accommodation. The study does not provide the CC%s used in the analysis, but the average CC% across all sectors in most CPEIRs is between 20% and 30%, suggesting that gross (ie unweighted) private CC investment was between USD 200m and 300m in 2016. The headline scenario assumes that, as the NCSD study was a first assessment it is likely to have missed some expenditure and assumes that the level of private CC expenditure is USD 400m, or 9.1% of total private investment.

Adaptation Benefits

The estimation of adaptation benefits is based on case study evidence from CC Impact Assessment (CCIA, also called CC Benefits Analysis or CCBA). More details are provided in Annex 3. The case studies include estimates of the total Net Present Value (NPV) and Benefit Cost Ratio (BCR)[14]. The BCR is split into two components, the Development BCR (DBCR) and the Adaptation BCR (ABCR). The DBCR is the total discounted benefits divided by total discounted costs when CC is not taken into account. The ABCR is the extra net benefits when CC is taken into account, which take the form or reduced L&D. Some studies also refer to the Adaptation Benefit Share (ABS) which is given by ABCR/BCR. An adjustment factor is applied to convert the discounted benefits derived from the BCR analysis to undiscounted benefits in the GDP projections.

Cambodia has remarkably strong evidence from CCIA and there are now well researched case studies of the contribution of investment in most major sectors. These are summarised in Figure 8 below, which gives the results for 29 case studies. More details are provided in Annex 3. Many of these have been done as part of the CCFF and associated work to assist key line ministries to integrate CC into routine appraisal practices. These cases have been through several rounds of refinement, including detailed discussions with key officials and other stakeholders.

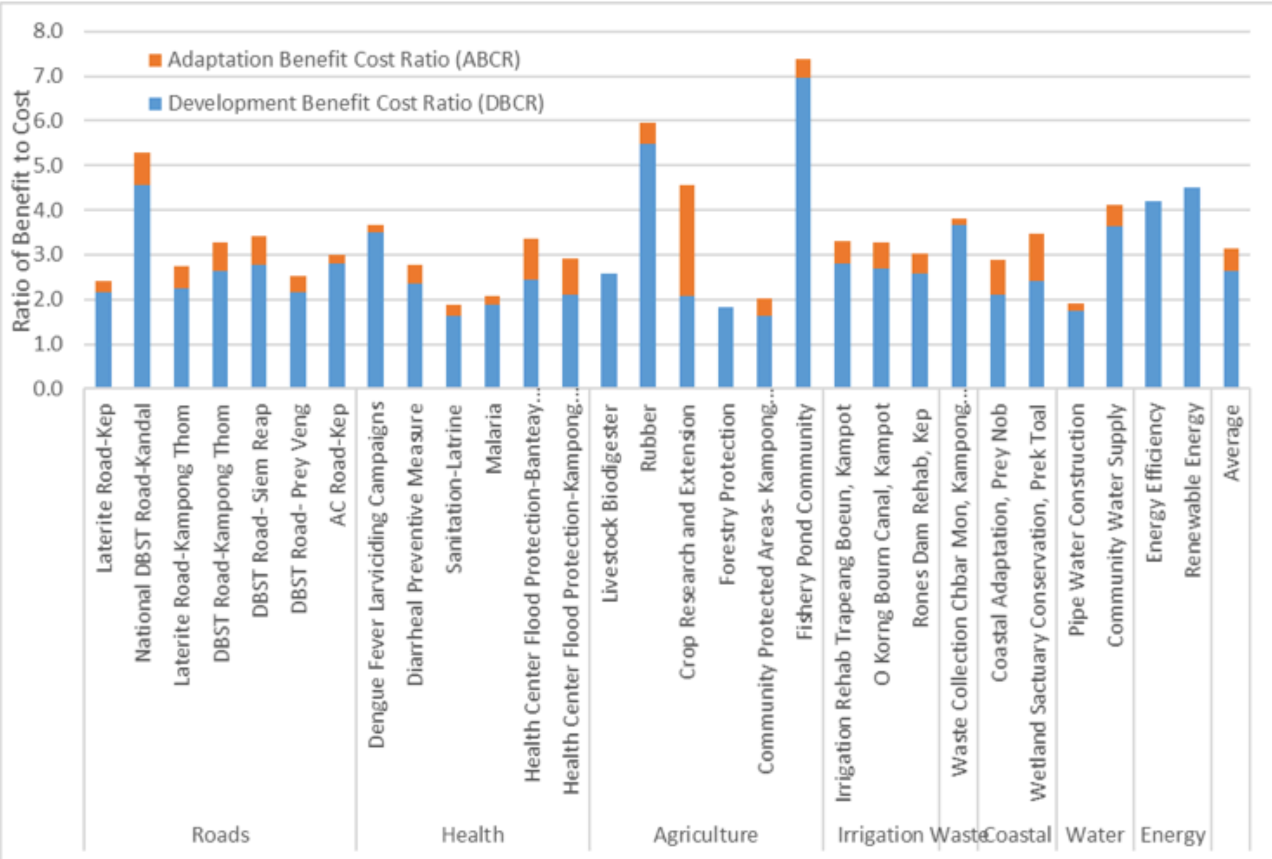
The CEGIM analysis of adaptation is done at an aggregate level and is not done separately for each sector. This decision is taken in the interests of simplicity, although it would be conceptually straightforward to use separate ABCRs for each sector, based on the case studies. The figure below suggests that most estimates of the total BCR are between 2.0 and 4.0 and that the ABCR is mostly between 0.2 and 0.7. The average BCR, weighted by expenditure, for the set of case studies is 3.1, which is relatively high by normal standards of cost benefit analysis, perhaps because it includes adaptation benefits, which have not normally been taken into account in past BCRs. CEGIM makes the more conservative assumption that the average BCR is 2.0.

[13] *CPEIRs show that significant recurrent expenditure also makes a contribution to adaptation, but this is excluded from the CEGIM analysis, in the interests of simplicity.*

[14] *The analysis describes the results of the CCIA mostly in terms of the way CC affects the BCR. This is useful because it allows the NPV of adaptation benefits to be calculated by multiplying scenarios for adaptation expenditure by the ABCR. To make this approach valid, the costs included in the BCR must be limited to those in the adaptation expenditure and any other costs should be netted out from gross benefits. CEGIM adopts a simplified approach to this, which is described in chapter 5.*

The weighted average ABCR is 0.5 and the average ABS is 16%. This is much higher than the 7% estimated in the CCFF, perhaps reflecting the more detailed analysis done in the case studies and the possibility that the case studies were selected to provide good examples of effective adaptation, which would therefore involve projects with higher ABSs. As with other parameters, CEGIM uses a conservatively triangulated level in-between these the case studies and the CCFF figure and assumes a ABCR of 0.25 (ie half the average from the case studies). Given the uncertainty about the extent to which the case studies are representative of all adaptation expenditure, these estimates should be treated with caution and their main function is to provide a starting reference framework for further work on CCIA.

FIGURE 8 Case Studies for Development and Adaptation Benefit Cost Ratios



**Note: the Benefit Cost Ratios refer to the level of development benefits and adaptation benefits divided by the costs. The total BCR = DBCR + ABCR. The Adaptation Benefit Share (ABS) is ABCR/BCR.*

The analysis assumes that the development benefits of adaptation expenditure are the same as the enefits from other development expenditure. Thus, the adaptation benefits are fully additional and there is no trade-off between adaptation and development benefits or 'crowding out' of development by adaptation. In practice, there are some cases where a trade-off does exist. For example, funding strong climate proofing (eg higher dykes) may mean the scale of programmes are reduced (eg shorter dykes). However, there are also many examples where programmes that contribute to adaptation also contribute to routine development (eg because they provide better protection from L&D relating to existing climate or because they require strong institutions that build resilience to shocks other than those related to CC). There are also many policies that provide opportunities for 'win-win-win' benefits to development, adaptation and mitigation (eg public transport and energy efficiency and access).

04
CEGIM Projections and CC Impact

4.1 National Level CC Impact

Growth without CC

Without CC, GDP grows at an average rate of 6.9%, in real terms, and absolute GDP is 1.4 times higher in 2020 than in 2016, 3.1 times higher in 2030, 5.9 times higher in 2040 and 9.75 times higher in 2050. Average growth in real GDP per capita over the period is 5.9%. These growth rates are roughly consistent with growth rates in per capita GDP over recent decades, both in Cambodia and in countries that are several decades ahead of Cambodia. For example, China has consistently grown and close to 10% and Malaysia, Thailand and Vietnam has sustained growth at above or close to 5%.

The underlying growth projections provide some confidence that the model is working well, but the primary purpose of CEGIM is to show the relative impact of CC on economic growth, and the absolute levels of growth are of secondary significance, beyond giving confidence in the structure of the model.

Impact of CC

Table 9 and Figure 9 present the headline results of the CEGIM analysis on CC impact, assuming:

a) the mid-level CC scenario (ie equivalent to A1 or RCP4.5 in the IPCC scenario terminologies)
b) current levels of adaptation are maintained

The reduction of absolute GDP caused by CC by 2020 is 0.4% of GDP, which is small but significant. By 2030, absolute GDP will be 2.5% lower as a result of CC. This is sufficiently large to influence macroeconomic planning, but it still only means that GDP will be 3.00 times higher, instead of 3.08 times, which is only a modest difference. The impact of CC steadily increases and absolute GDP is 6.0% lower in 2040 and 9.8% lower in 2050. The average growth rate for the period from 2016 to 2050 falls from 6.9% without CC to 6.6% with GDP and the growth rate in 2050 falls from 4.5% to 4.2%. These are more serious impacts and reflect the fact that the impact of CC increases over time, both because of the severity of CC itself and because of the cumulative effect through reduced investment and growth. The NPV of the GDP growth paths to 2050 is 4.4% lower as a result of CC.

TABLE 9 Reduction in GDP Caused by CC

	Reduction caused by CC
GDP in 2020	0.4%
GDP in 2030	2.5%
GDP in 2040	6.0%
GDP in 2050	9.8%
NPV of GDP to 2050	4.4%

Sectoral Disaggregation

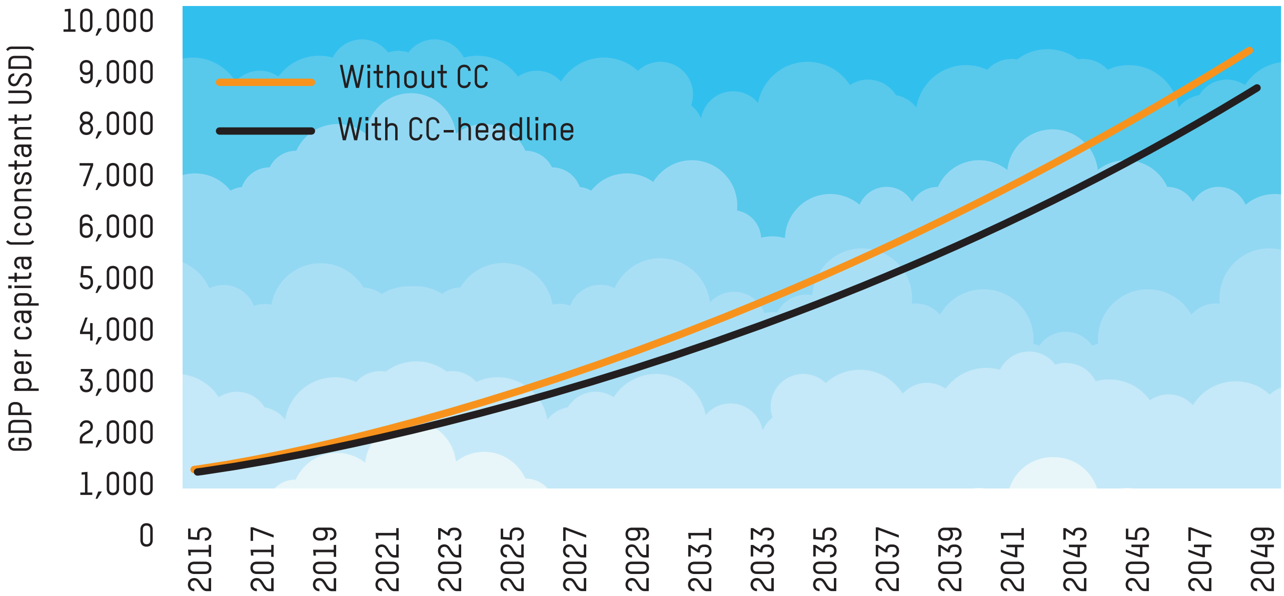
These headline estimates of CC impact take into account the different growth rates of each sector and, hence, the changing sector shares of L&D, including the reduced significance of relatively high losses in the agriculture sector. Sector growth rates vary considerable and are determined primarily by the savings/ investment rate, as well as being influenced by the rate of depreciation for the sector and the projections for capital and labour productivity. Some of the sector growth rates are surprising, including the relatively high growth rate for the agricultural sector. These reflect the relatively high levels of investment in these sectors, as described in the data sources used for calibration. Further work is required to understand the behaviour of some sectors.

To explore the significance of the sectoral disaggregation, the CEGIM analysis was also conducted at a national aggregate level, with a single production function calibrated using total national GDP, investment and labour. This version of the model is much simpler, but does not take into account the concentration of impact in some sectors. The national aggregate version of the model gives estimates of CC impact that are about 20% higher than when the sectoral details are taken into account. This is likely to be mainly because the declining importance of agriculture is not accounted for in the national aggregate analysis.

Development Status

Upper Middle Income Country (UMIC) Status (ie GNI per capital of $4036) is achieved in 2035 without CC and 2036 with CC. By 2050, Cambodia is still $4227 per capita short of High Income Country (HIC) Status (ie GNI per capita of $12236) of without CC and $5094 short with CC. This analysis takes into account the fact that UMIC and HIC status is based on GNI per capita, which is calculated by dividing the projected GDP by projected population and assuming that GNI continues to be 7% lower than GDP, as it has been in recent years. All projections are in real terms.

FIGURE 9 Preliminary Estimates of GDP with and without CC

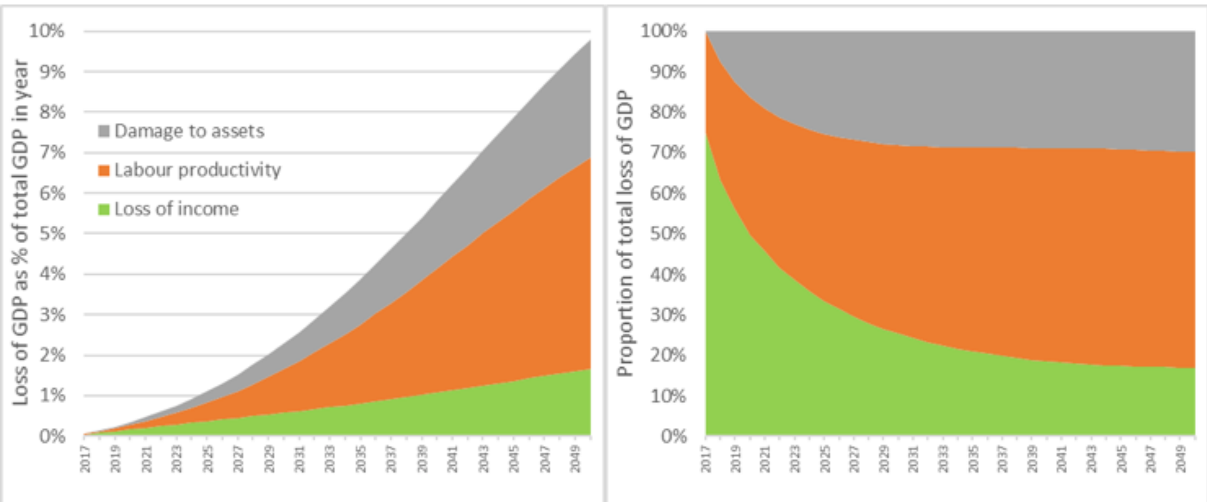


4.2 Impact by Type of L&D

CEGIM defines three distinct types of impact: loss of income, mainly from reduced natural resource productivity and reduced efficiency; declining labour productivity arising from heat stress; and damage to assets arising from extreme events.

Figure 10 shows the relative importance of each of the three types of L&D[15]. By 2050, reduced labour productivity accounts for 57% of all L&D, loss of income accounts for 17% of all L&D and damage to assets accounts for 26% of L&D and is spread across all sectors. The figure shows that all types of L&D grow at a similar rate, but that loss of income is more important in the early years and is gradually replaced by reduced labour productivity as the main source of L&D. This is mainly because loss of income occurs primarily in the agricultural sectors which grow less fast than the other sectors.

FIGURE 10 Type of L&D expressed as % GDP and % total L&D



[15] *The model includes 'switches' that turn each of these impacts on and off, so that the individual impact of each can be isolated and the relative importance of each can be assessed. The switches turn off/on both the L&D and the adaptation benefits associated with the type of L&D. Figure 10 shows the results of running the model with each of the types of L&D in isolation .*

The importance of the different types of L&D depends primarily on the extent of the L&D itself, as described in section 3.2. It is also affected by the focus of adaptation expenditure. There is no clear evidence of the extent to which adaptation expenditure aims to reduce each of the three types of L&D. However, it seems clear that there is still very little, if any, public policy or expenditure associated with heat stress and labour productivity. CEGIM assumes that the current split of adaptation expenditure is 50:0:50 (for income, labour and damage respectively) and that there will be a gradual shift to a 25:50:25 split in 2050, in equal annual steps.

4.3 Impact by Sector

CEGIM projects the growth of each sector independently, based on the capital stocks, investment and labour availability for each sector, the assumptions on changing capital and labour productivity and the way in which L&D affects each sector differently. For the larger sectors, the projections appear to follow expected patterns. However, some smaller sectors have had relatively high public and/or private investment in recent years and, in the absence of more detailed evidence, CEGIM assumes that adaptation expenditure is proportional to total sectoral investment. This means that some of the smaller sectors actually grow faster with CC than without because the adaptation benefits are slightly higher than the L&D estimates. The figure below summarises the evolution of economic impact, by main economic sector and by type of L&D.

FIGURE 11 Share of Economic Impact of CC by Main Sector and Type of L&D

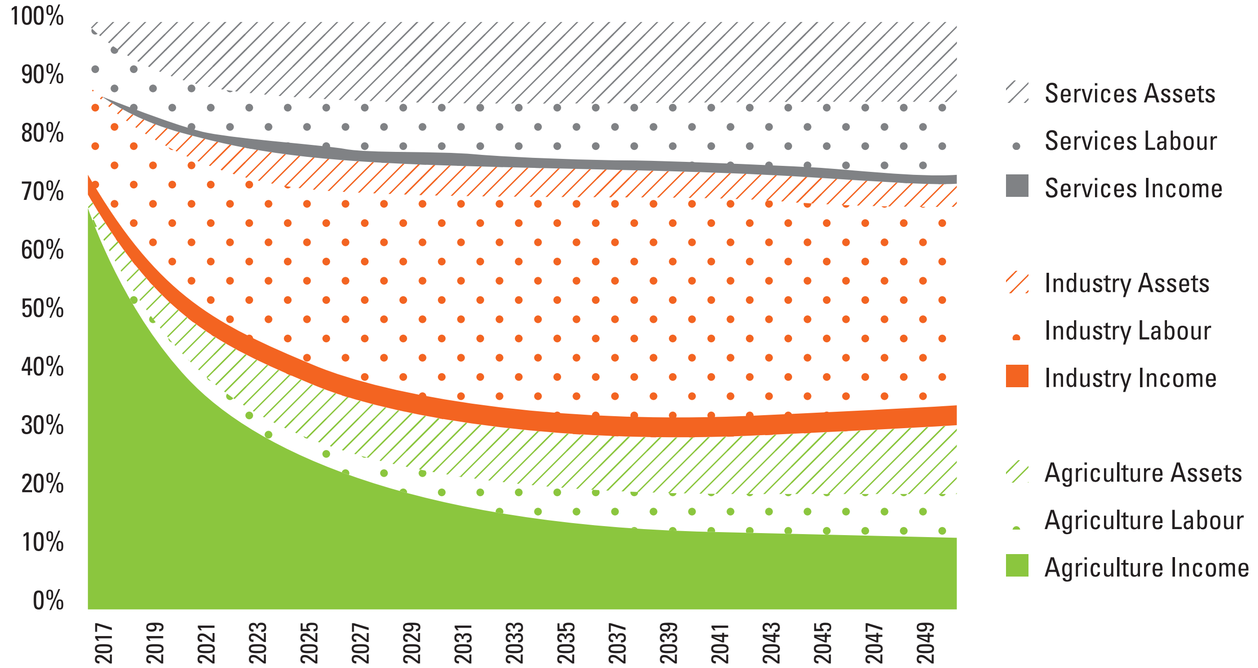


Figure 11 shows that the agriculture sectors account for the majority of economic impact in the early years but the importance of the industrial sectors gradually become more important accounting for nearly 45% of total economic impact by 2030.

Reduced labour productivity accounts for 57% of all L&D and this is spread across all sectors. Loss of income accounts for 17% of all L&D and is concentrated in the four agricultural sectors. Damage to assets accounts for 26% of L&D and is spread across all sectors, being especially significant for service sectors.

4.4 Comparison with Previous Modelling

The ADB 2009 Study for SE Asia. The most directly comparable international work on the economic impact of CC is the study undertaken by ADB in 2009 on CC impact in SE Asia (ADB 2009). This study reported various results, but the one that seems to be most comparable with the CEGIM analysis is the drop in GDP of 5.7% by 2100. This includes economic losses as well as health impacts. It does also include environmental impact, which is not included in the CEGIM analysis. It is not clear how to interpret the 5.7% (see the introduction), but the interpretation that gives the most serious impact of CC would seem to be that the results relate to the NPV of growth paths, in which case the reduction in absolute GDP by 2050 would be 4.3% and the reduction in the NPV of GDP growth paths to 2050 would be 1.4%[16], although these figures depend on the assumption the study uses for how CC damage progresses through the period and on the discount rate used, neither of which is mentioned in the ADB study. Thus, the current study suggests that the economic impact is about 3 times higher than suggested in the ADB study. The difference is likely to be caused by:

- the fact that Cambodia is more vulnerable than the countries considered in the ADB study (ie Thailand, Indonesia, Vietnam and the Philippines)
- new evidence of the impact of CC in key areas, including the impact of heat stress on labour productivity, the level of damage caused by floods and droughts (based on the three big events since the ADB study) and the evidence provided by the SREX study on changing frequencies in extreme events

The CC Financing Framework (CCFF)

The Cambodia CCFF was produced in 2015 and was the first study in the world to combine analysis of past CC expenditure, assessment of adaptation effectiveness and future financing scenarios into a review of the extent to which planned CC policy and expenditure would reduce the expected L&D from CC. The assessment of exposure to sectoral L&D was roughly consistent with the CEGIM assessment, although the CCFF did not include evidence of the impact of heat stress on labour productivity. The CCFF concluded that the expected impact would grow steadily to about 3.5% of GDP by 2050. However, it assumed that the full effect of this impact was on reduced growth (ie growth in 2050 was expected to be 1.5% with CC instead of 5% without CC) and so the cumulative impact on absolute GDP was very high. CEGIM results suggest that the full economic impact of CC is less than half the very high figures suggested by the CCFF analysis.

Similar approaches (ie assuming that all L&D reduces growth) have been used in CCFF work in other countries and in states in India. Dissatisfaction with the simplistic approach to growth impact in this approach has been one of the main reason for developing CEGIM, to identify the various ways in which L&D affects growth.

4.5 Sensitivity Analysis

Sensitivity to CC Scenario

The CC Scenario affects the change in the temperature rise and the frequency of extreme and irregular rainfall events. Climate science models seem to suggest that the implications of temperature rise are not strictly linear and become exponential worse as temperature rises. However, for the purposes of applied policy making, the impact can be considered to be roughly proportional to temperature rise. Most of the calibration of L&D is based on a mid-range CC scenario (eg SRES B2/A1 or AR5 RCP4.5). Worst and best case scenarios involve temperatures that are very roughly plus or minus 30% to 40%. The level of economic impact is likely

[16] *This reconstruction of the ADB analysis assumes that the CC impact growth linearly and cumulatively over the period and that the discount rate used in estimating NPV is 5%.*

to be roughly proportional to these ranges. Thus, if the headline result is for absolute GDP in 2030 to be 2.7% lower, then this could range from about 2% to 4%, depending on which CC scenarios actually occurs.

Sensitivity to Loss and Damage

L&D estimates are obtained from a wide range of sources, few of which have any explicit confidence limits. Many estimates can be considered to be at least +/- 50%. However, the use of triangulation between different sources does reduce the range of uncertainty. It is not possible to obtain a specific estimate, but the table below gives a preliminary estimate of the confidence limits for each of the three main sources of L&D. Key assumptions include the following:

- For agriculture, the analysis is complex and includes many variables, which leads to a low confidence that any individual estimate is correct. However, there are many different sources of evidence, applied from different perspectives, which compensates for the wide range of evidence.
- The evidence on heat stress and labour productivity is strong, partly because it can be easily researched. There is also a wide body of research with consistently similar conclusions. The main sources of uncertainty are about application of this research in Cambodia, but some research has been done on this.
- For damage to infrastructure, there is high confidence that the sources of evidence available provide accurate estimates for the variable they measure, but there is some uncertainty about whether they cover all damage.
- Overall, the different sources of L&D are additive, rather than multiplicative. The overall range is likely to smaller that the worst case because it is unlikely that all sources of L&D will be at the high or low end of the their range at the same time.

TABLE 10 Ranges for Key Sources of L&D

	Share of L&D	Confid-ence	Triang-ulation	GDP 2030 Reduction	
				Mid[1]	Range
Impact on agriculture	17%	Low	High	0.8%	+/- 40%
Heat stress of labour productivity / health	57%	High	Mid	1.3%	+/- 25%
Damage to infrastructure	26%	Mid	Mid	0.7%	+/- 40%
All sources at the same time (multiplicative)	100%			3.2%[2]	+/- 30%

[1] *The figures refer to the reduction in absolute GDP in 2030, assuming no adaptation*

[2] *The effect of all sources at the same time is greater than the sum of the three individual effects because there are some cumulative and multiplicative effects.*

Sensitivity to Capital and Labour Productivity

The headline projections assume that the trends in productivity for both capital and labour continue at the same rate as they have for the last 23 years. However, the government recognises that current productivity is Cambodia is relatively low, especially for labour productivity, and that there should be good potential for improving productivity, especially with new opportunities arising from technology and the fourth industrial revolution, which Cambodia is well placed to exploit[17]. MEF are considering a range of policies to encourage improved productivity, which are likely to involve collaboration with the private sector and the provision of related public goods, including information and research, as well as incentives such as grants, finance and regulations. If these policies resulted in a one-off uplift in Cambodia's capital and labour productivity by 1%, after which recent trends continued, then the average growth rates to 2050 would increase significantly to 8.4% without CC and 8.0% with CC.

With improved baseline productivity, the impact of CC on GDP would be slightly higher than the headline impact, with the NPV of GDP being 5.6% lower with CC, compared to 4.4% lower with the assumptions about productivity in the headline scenario. The slightly greater vulnerability of the economy to CC with higher productivity probably occurs because the impact of CC on labour productivity and on capital assets is proportionally higher, when the underlying productivity is higher.

Using a Cobb Douglas Production Function

The headline projections are presented using the linear production function. A Cobb Douglas production was also fitted and the R2 value for the regression was high (94.9%), although slightly lower than for the linear production function (97.2%). However, the Cobb Douglas production function proved difficult to use because it delivered exponential growth that is unrealistic in the mid to long term. The higher sensitivity of the Cobb Douglas production function probably occurs because it allows capital productivity to increase over time and, hence, any CC impact on capital (either directly through damage or indirectly through investment) will be greater, especially in the later years. The sensitivity analysis illustrates the limits of neoclassical modelling, especially for the longer term future. However, even though the absolute GDP figures in the longer term may be highly speculative, the relative impact of CC over this period may still be meaningful, especially when supported by sensitivity analysis to explore the sensitivity of the results to the main assumptions.

Sensitivity to Investment and Depreciation Assumptions

The results are influenced by the level of investment in the economy because this affects the capital stocks and the extent to which losses in income feed through into reduced investment and, hence, reduced growth. The headline analysis uses a revised estimate of investment in 2016 of 29.1% of GDP. Reducing this makes little difference to the results, provided it affects both past and projected levels of investment, because the calibration adjusts the production functions to reflect the assumptions about past investment and the model assumes that future investment stays at this level. Depreciation has a strong effect on the overall growth, but has limited effect on the marginal impact of CC on GDP. The effectiveness of investment and increased capital assets is sensitive to the assumption on capital productivity. This is assumed to grow roughly in line with past growth for the early years of the projections and then gradually decline to zero growth in productivity by 2050.

4.6 Income Equality

The CEGIM analysis provides only limited insight into the impact of CC on equality. The analysis reported here should be considered highly preliminary and is included primarily to illustrate what might be possible with more research and improved source data. Three ways in which inequality is influenced by CC are explored.

A. Changes in inequality between sectors are captured through the differential sector growth rates and assumptions on changes in labour productivity.

[17] *Assuming capital and labour productivity continue to improve at the same rate as in the past is a conservative assumption as the pace of technological change in Cambodia is likely to accelerate. In the CEGIM model, this would make GDP more sensitive to CC because changes in capital assets and labour would result in larger changes in GDP. However, new technologies are likely to involve capital assets that are less vulnerable to CC and labour in jobs that are less vulnerable to heat stress, so the L&D associated with damage to assets and labour productivity might decline. This is a detail that could be explored in more detail in further work.*

B. There is some limited evidence on inequality within sectors and the differential sector growth rates thus reflect the implications of this on total inequality.

C. Changes in inequality within sectors will also be influenced by the way in which the three types of L&D damage contribute to increased inequality. Although there is a large literature that claims that CC affects the poor more than average, there is little empirical evidence on the extent of this effect and the CEGIM application has not yet taken this into account.

BOX 4 Climate Change and Income Inequality

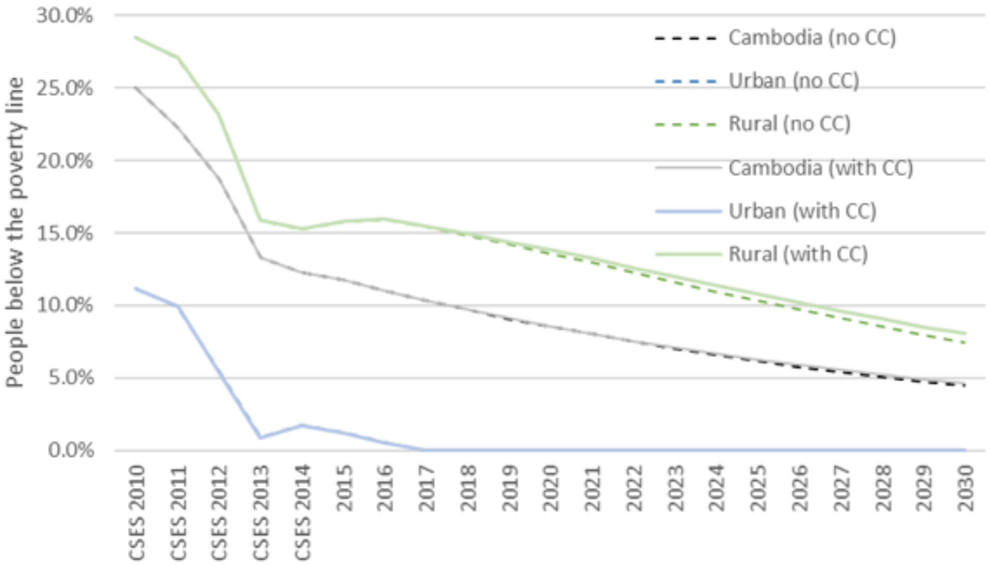
Most CC vulnerability assessments assume that CC will affect poorer households proportionally more than average households and so lead to higher inequality. There is growing international interest on the ways in which this happens and the extent of the increase in inequality (UNDESA 2016). There is still only limited empirical evidence of the scale of this impact, but there are some sources that are related to each of the three types of L&D defined in the CEGIM (ie loss of income, reduced labour productivity and damage to assets.

- For loss of income, the WESS 2016 report provides evidence from Mexico which suggests that the proportional reduction in agricultural incomes arising from CC for the lowest income decile is roughly double that of the highest. In the absence of evidence for Cambodia or other countries in South or South East Asia, this can be used as a rough rule of thumb to illustrate the potential implications of CC for income inequality and poverty.
- For loss of labour productivity arising from heat stress, no direct evidence has been found about how this affects income distribution within sectors. However, the impact is partially taken into account in CEGIM through the analysis of increased income inequality between sectors, because the three types of labour identified (heavy, manual and other) are roughly correlated with average sectoral incomes, so higher losses in heavy labour (ie agricultural and construction) lead to lower average sectoral incomes in these sectors, thus increasing overall inequality.
- For damage to assets, there is limited empirical evidence. One study of panel data in 83 countries (not including Cambodia, but including Thailand, Indonesia and the Philippines) suggested that there was a significant increase in income inequality in the year after a natural disaster, but that this impact disappeared in the following two years, possibly because of the effect of disaster recovery measures(Yamamura 2013). The study suggested that an average natural disaster increases the Gini coefficient by 0.01 in the year after the disaster.

Poverty Rate

The way in which economic growth affects the poverty rate is a complex subject. The evidence from the Cambodia Socio Economic Survey suggests that economic growth leads to a roughly proportional increase in incomes for all deciles. Assuming this is the case, the GDP projections can be used to analyse trends in the poverty rate and this is presented in Figure 12, which shows that CC has only a very limited impact on the reduction in poverty up to 2030, because the impact of CC on economic growth up to 2030 is still small.

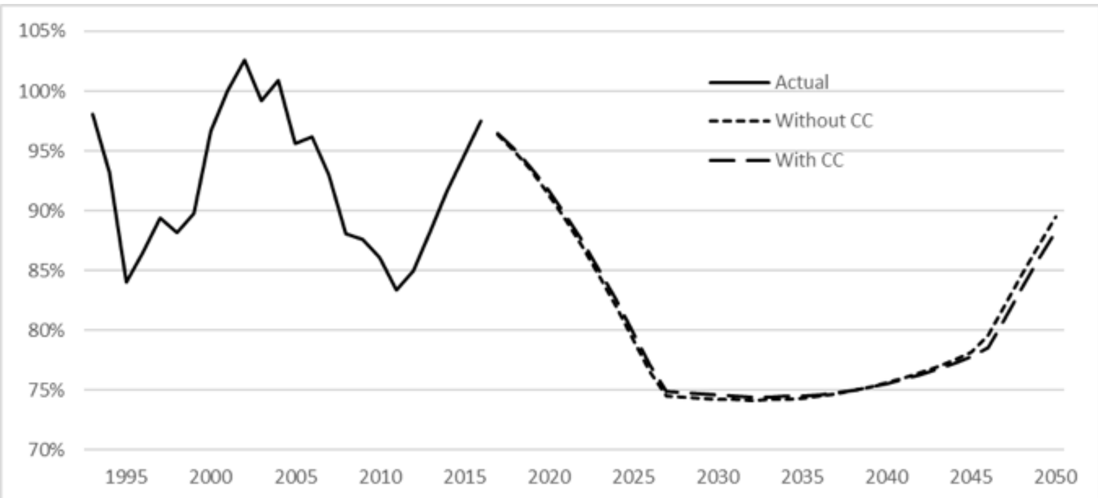
FIGURE 12 Impact of CC in Poverty Rate



Income Inequality

CEGIM includes data and projections for sectoral GDP and sectoral GDP per capita, which allow for an index of inequality of incomes between sectors to be compiled. The inequality index is the absolute deviation of sector GDP per capita from national mean GDP per capita, weighted by the employment in the sector. Figure 13 presents the results of the analysis and shows considerable variation. The projections suggest that growth in the sectors with lower income is initially higher than average, thus reducing inequality between sectors, but that this stops in about 2027 and the pattern is strongly reversed from about 2045 onwards. More research is required to understand the reasons for these trends.

FIGURE 13 Trends in Inequality Between Sectors



Gender Income Inequality

It is often thought that female headed households are more affected by CC than male headed households, both because their livelihoods are more often base on natural resources and because they are typically more vulnerable in general. The new focus on the impact of heat stress on labour productivity is likely to affect women strongly, but it is also likely to affect men involved in heavy manual work, so it is not clear whether the next impact on women will be greater than on men. In theory, CEGIM should be useful for analysing the relative importance of these processes. Unfortunately, information on gender and poverty in Cambodia is not easily available. Households headed by women accounted for 22% of all households in 2012. The poverty rate amongst households headed by women was 22.5%, compared with 20.1% for households headed by men (ADB 2014). This suggests that differences are not large. However, there are a number of reasons for suspecting that these figures hide greater inequality.

- There are significant variations between sectors, with women having a higher participation in agriculture and manufacturing. As agriculture accounts for a large share of employment and has significantly lower incomes than other sectors, this is likely to generate large gender income differentials.
- Within sectors, there is some evidence that households headed by women are disadvantaged. The CSES suggests that households headed by women own landholdings that are 0.49 times those owned by households headed by men[18]. And a recent ILO study suggested that raw gender pay differentials (ie unadjusted for education etc) in industry were about 16% in Cambodia.
- There is good qualitative evidence that households headed by women are more vulnerable to CC L&D, so the impact of CC is likely to increase gender differences. Adaptation policies are likely to benefit households headed by women even if they are not explicitly targeted, simply because the reduce vulnerability in general. Adaptation is therefore likely to reduce part of the increased inequality caused by CC L&D.

Unfortunately, there is insufficient evidence on differences in incomes between households headed by women and men without CC to allow for any quantitative assessment of the impact of CC on these differences.

Adaptation and Equality

Because adaptation programmes reduce L&D, they will normally increase equality, even if they are implemented without deliberate targeting on poor households. But many adaptation programmes are targeted on the most vulnerable households and so will have an even stronger impact on improving equality. One international review suggested that the policy response to disasters reversed all the inequality effects of the disaster within two or three years (Yamamura 2013). Similar performance in reversing a tendency for CC to increase inequality should be possible with adaptation aimed at reducing losses for agricultural income and labour productivity.

4.7 Backcasting

It is clear that CC has been significant in Cambodia for at least 20 years and the impact of CC over the last few decades is important, not least because many climate scientists argue that, at local levels the evidence from recent climate trends is probably more reliable than the evidence from downscaled climate models. Understanding recent trends is therefore critical to sound evidence-based analysis of the economic impact of CC and of adaptation policy.

CEGIM has been used to explore what would have happened to economic growth since 1993, if CC had not taken place. In theory, this analysis should be based on data on trends in temperature and in rainfall patterns,

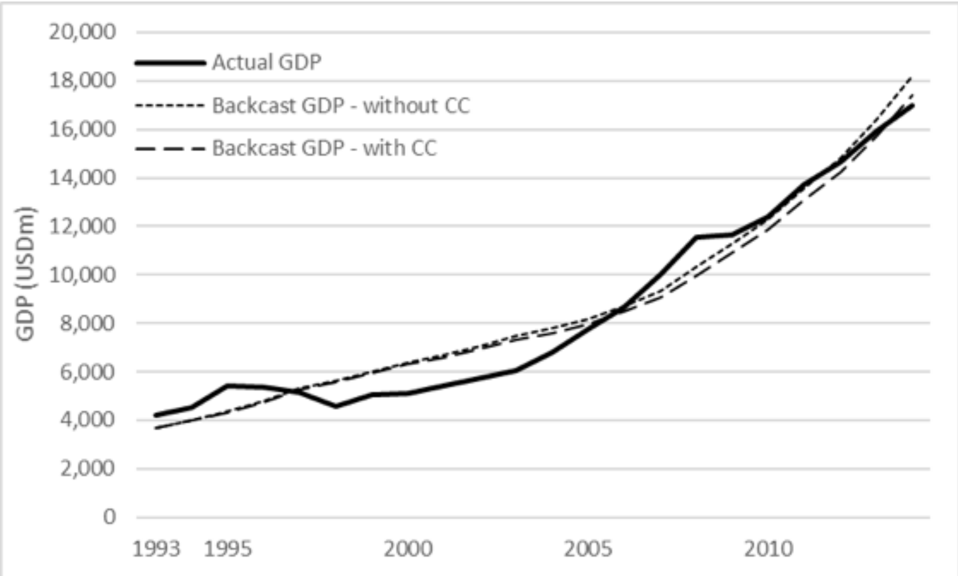
[18] *The 22% of households headed by women own only 12.2% of land*

including changes in the frequency of floods, droughts and variable rainfall patterns. However, evidence on trends in recent decades is not readily available. Instead, CEGIM has assumed that the expected rate of change in climate that is defined in the projections in the CC scenarios has also applied in the period from 1993 to 2016. CEGIM can therefore be used to estimate how the economy would have grown if there were no CC over the period.

Because the actual data for GDP include the full impact of CC, the production function should, in theory, be calibrated to include the three damage terms (ie loss of income, reduced labour productivity and damage to assets). However, this would mean that a relatively brief data series would be required to provide evidence for calibrating at least 6 different parameters in the production function. Given the quality of the data, it is unlikely that this would produce useful results. There are also challenges in defining the equations that should be used for calibration, given the indirect way in which damage to assets affects GDP. A brief experiment to introduce the CC severity index as an independent variable confirms that calibration is unlikely to be reliable.

Instead of calibrating the production function including L&D terms, the CEGIM backcasting adopts a simpler, compromise approach. It retains the simpler calibration of the production function, ignoring L&D in the period from 1993 and 2016 and it then assumes that the aggregate damage experienced over the next 23 years is a good indication of the aggregate damage that is likely to have occurred in the past 23 years. This produces the results in the figure below.

FIGURE 14 Actual GDP and Modelled GDP with and without CC (1993-2014)



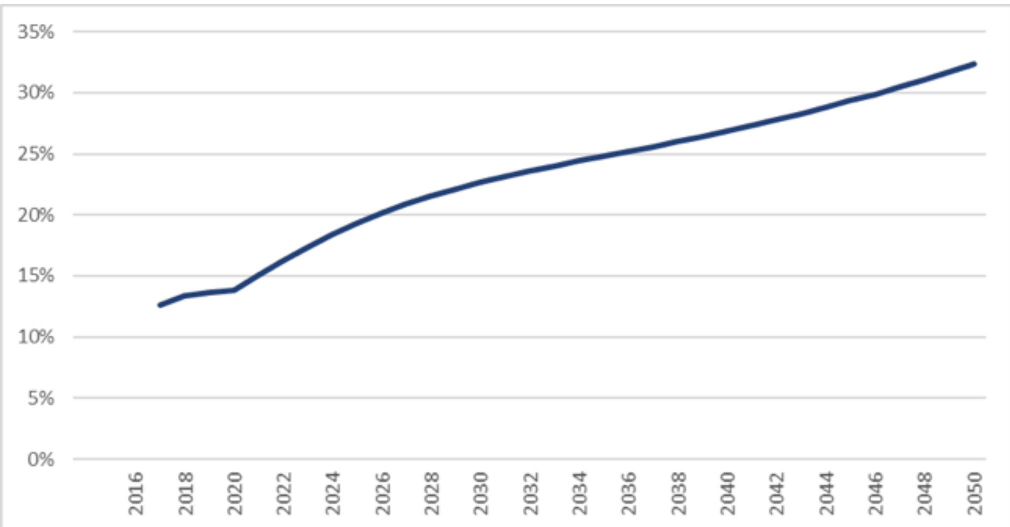
05

The Scale of Adaptation Needs

The CEGIM analysis allows for an exploration of the realistic potential for increasing adaptation effort. Section 2.3 describes the theory of how adaptation policies[19] are included in CEGIM. Section 3.7 describes the evidence base for existing adaptation policy.

The headline analysis described in the previous chapter assumes that current levels of adaptation investment are maintained. The figure below shows the extent to which the current levels of adaptation expenditure will reduce the expected economic impact. The figure shows that, although the severity of economic impact increases over time, the gradually cumulating effects of adaptation expenditure are also increasing over time, and the share of the L&D that is avoided as a result of adaptation gradually rises to over 30% in 2050[20], giving an adaptation gap of about 67%, which is less than that estimated in the CCFF, but still suggests that significant strengthening of adaptation is required, either through increased expenditure or through improved effectiveness.

FIGURE 15 The Proportion of CC Economic Impact Addressed by Adaptation



[19] *The analysis is limited to CC adaptation and does not consider mitigation because Cambodia's contribution to mitigation has a negligible effect on GDP since Cambodia's mitigation is mixed with global mitigation and Cambodia accounts for only 0.11% of global emissions.*

[20] *The analysis of adaptation impact in the early years is complicated by the need to make assumptions about the impact of recent past CC expenditure, which will contribute to adaptation even before CEGIM considers new economic impact, starting from 2017. The analysis assumes that the previous 5 years of public expenditure will make some contribution to adaptation, even though the analysis ignores the economic impact of CC before 2017.*

CEGIM is used to explore the potential for closing the adaptation gap. This is done by defining three scenarios for each of the elements:

- a no adaptation scenario[21]
- a current adaptation scenario, based on current levels of adaptation
- a high adaptation scenario, in which each of the elements reflects the highest levels of improved adaptation that are considered possible with increased priority given to adaptation.

The adaptation scenarios are defined by the following key features.

1. The level of total public investment is assumed to rise from the current level of 29% of GDP to 34% in the high adaptation scenario. It is assumed that, in the no adaptation scenario, the level of investment is still 29%, but the current funding for adaptation is switched to investment in development.
2. The CC share in public investment refers to the share of total public investment that makes some contribution to CC. This includes most investment in agriculture, water, energy, roads and disaster management and some investment in primary health. It excludes most social expenditure, which is likely to require at least 25% of total public investment, giving a high adaptation scenario level of CC share of 75%.
3. Cambodia currently receives only dedicated international climate funds equivalent to only 0.25% of GDP, although a significant share of development assistance does contribute to adaptation. The high adaptation scenario assumes this will rise to 1.0% of GDP.
4. The CC share in private investment is estimated at 6.8%, based on the recent UNDP study on private CC investment in Cambodia. This is double in the high adaptation scenario as a result of: a) government policies (eg regulations, incentives, information) encourage private adaptation; and/or b) the private sector become more aware of the risks and makes its own decisions to invest in adaptation.
5. The overall effectiveness of investment is estimated to deliver an average BCR of 2.0 at present. This is assumed to increase to 2.4 in the high adaptation scenario as a result of improved planning and project design.
6. The Adaptation Benefit Ratio (ABR) refers to the total benefits that are derived from reduce L&D (ie the adaptation benefits) expressed as a ratio of costs. This is currently estimated at 0.25 and is assumed to rise to 0.35 in the high adaptation scenario as a results of: a) the CC related investments that are approved include a stronger focus on the most CC relevant programmes; or b) the design of each programme is more rigorous in address CC threats.

The assumptions and results of this analysis are summarised in Table 11 and Figure 16, which suggest that current levels of adaptation will reduce the loss of NPV of GDP by nearly 30% and that a high adaptation scenario could reduce the loss of NPV GDP of 2050 by 59%, leaving 41% of the potential L&D as the Adaptation Gap. The high adaptation scenario focuses on improved efficiency and effectiveness and should be achievable without significant reduction in development expenditure. However, increasing public investment could have some implications for crowding out private investment and this requires further study.

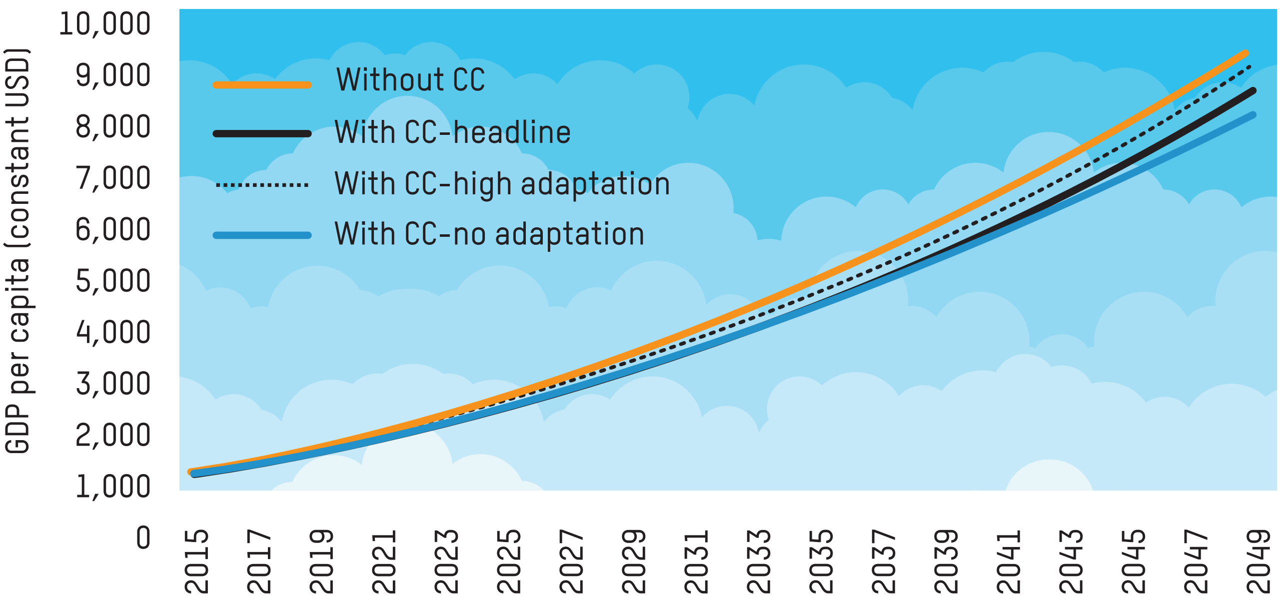
[21] *The no adaptation scenario includes some adaptation spending where this occurs as a results of normal development spending that would happen even without taking any account of CC and which makes incidental contributions to adaptation.*

TABLE 11 Key Parameters Defining Policy Scenarios

	Adaptation Scenario		
	No	Current	High
Elements of Adaptation Scenarios			
1. Public Investment (%GDP)	29%	29%	34%
2. CC Share in Public Investment (% total)	59%	68%	75%
3. International Climate Funds (%GDP)	0%	0.25%	1.00%
4. CC Share in Private Investment	2.3%	6.8%	13.6%
5. Effectiveness (BCR) or Expenditure	1.8	2.0	2.4
6. Focus on Adaptation (ABR)	0.00	0.25	0.35
Results			
Reduced GDP in 2030	3.2%	2.5%	1.7%
Reduced GDP in 2050	14.5%	9.8%	4.9%
Reduced NPV of GDP 2017 to 2050	6.1%	4.4%	2.6%
Average GDP growth 2017 to 2050	6.4%	6.6%	6.8%

These estimates of the potential scale of adaptation needs are roughly in line with other estimates obtained from previous work in CCFFs in South and South East Asia, which suggest that current adaptation efforts will address about a quarter to a third of the adaptation needs, leaving a 'gross gap' of 67% to 75%. But it is clear that some of the L&D from CC cannot be avoided in a cost-effective manner, and so should not be avoided. There are some suggestions in the literature that the share of L&D that should not be avoided could be up to one third (Stern 2006), leaving a 'net gap' (ie excluding the L&D that should not be avoided) of 33% to 50% of total L&D. International work on exploring the scope for accelerating the adaptation effort is still at an early stage, but simple scenario analysis, similar to that described above, suggests that it should be possible to halve the net adaptation gap without creating demands on public expenditure that will threaten the focus on development. The CEGIM adaptation scenario analysis roughly confirms this pattern, suggesting that a strong and proactive adaptation strategy can result in more than half the L&D being avoided, without reducing resources devoted to development.

FIGURE 16 Reduction in Absolute GDP as % of GDP, Three Adaptation Scenarios



06

Conclusions and Recommendations

6.1 Adaptation Strategy

The previous chapter showed that current adaptation efforts should allow Cambodia to avoid about one third of the potential L&D that could occur without adaptation. It also concluded that it should be possible to increase the share of L&D that is avoided to over half, with a stronger focus on adaptation, without having a major impact on development investment. This section considers the possible content of a stronger adaptation strategy.

CC Strategic Statements

The key features of Cambodia's strategic response to CC are contained in the following statements of adaptation strategy.

- The Cambodia CC Strategic Plan (CCCSP) was produced in 2013 and contains 8 strategic objectives, implemented by 60 strategies. The CCCSP is comprehensive and covers all sectors of economy, society and environment. The CCCSP provides some prioritisation by defining three phases: an immediate 2 year phase devoted to more structured planning; a medium term phase (2014-2018) focusing on building institutions and financing and a few high priority programmes; and a long term phase (2019-2023) scaling up adaptation and mitigation programmes.
- The CCCSP called for the preparation of a CC Financing Framework (CCFF) and Action Plan (CCAP) and this was published in 2015. The CCFF provided CC financing scenarios which were used to give CC expenditure ceilings for each of the next 5 years to the 9 public organisations (ie line ministries and agencies) most involved in CC. The ceilings were then used by the 9 public organisations to prepare costed sectoral CCAPs, with a total of 117 actions, including 10 investment projects, 39 actions delivering services, 36 actions relating to policy and 32 actions for institutional strengthening.
- Cambodia's Second National Communication (SNC) to the UNFCCC was published in 2015 and includes an assessment of vulnerability in 4 key sectors: agriculture, forestry, coastal protection and health. The adaptation response describes a small number of short and long term activities for each sector covering the main areas of vulnerability and a range of public services, including innovation, infrastructure, information and institutions.

Matching Adaptation Effort to Type of L&D

The CCCSP and CCAP and INDC provide a relatively comprehensive list of CC actions, including: farming systems and drought resilience; livestock and fisheries resilience; forestry protection and management; irrigation and protection against flood and sea level rise; energy security and saving, including in transport; CC related health and education programmes; flood proofed roads, housing and other infrastructure; and institutions and information related to CC and disaster management. Table 12 summarises the main priorities in the INDC, CCAP and CCCSP and classifies the actions and strategies that contribute to the three main sources of L&D.

TABLE 12 Priorities in the INDC, CCAP and CCCSP and Types of L&D

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Type of Loss and Damage</th><th rowspan="2">Mitiga-tion</th></tr>
<tr><th>Loss of income</th><th>Damage to assets</th><th>Labour Product-ivity</th></tr>
<tr><th colspan="2">Paris Agreement INDC (2015) - priority actions</th><th colspan="4">Number of Actions</th></tr>
<tr><td>1</td><td>Community based adaptation and ecological resilience</td><td colspan="3">1</td><td></td></tr>
<tr><td>2</td><td>Improved resilience of protected areas</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td>3</td><td>Early warning and climate information systems</td><td colspan="2">1</td><td></td><td></td></tr>
<tr><td>4</td><td>Flood protection dykes for agriculture/urban</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td>5</td><td>Water pumping and groundwater recharge for droughts</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Agriculture systems proofed against water variability</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Sea dykes to protect coastal agriculture</td><td colspan="2">1</td><td></td><td></td></tr>
<tr><td>8</td><td>Crop varieties suitable to each agroecological zone</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Adaptive agricultural production systems</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Climate proofed roads</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td>11</td><td>Strengthened malaria control</td><td></td><td></td><td>1</td><td></td></tr>
<tr><td>12</td><td>Programmes for other climate sensitive diseases</td><td></td><td></td><td>1</td><td></td></tr>
<tr><td>13</td><td>CC studies (impact, projections, mainstreaming)</td><td colspan="3">1</td><td></td></tr>
<tr><td></td><td>Mitigation actions</td><td></td><td></td><td></td><td>7</td></tr>
<tr><th colspan="2">CC Action Plan (2013) - sectors</th><th colspan="4">Number of Actions</th></tr>
<tr><td>1</td><td>Agriculture and agro-industry</td><td>6</td><td>1</td><td></td><td>2</td></tr>
<tr><td>2</td><td>Rubber</td><td>4</td><td></td><td></td><td>1</td></tr>
<tr><td>3</td><td>Livestock</td><td>2</td><td></td><td></td><td>1</td></tr>
<tr><td>4</td><td>Forestry</td><td>3</td><td></td><td></td><td>2</td></tr>
<tr><td>5</td><td>Fisheries</td><td>4</td><td></td><td></td><td>1</td></tr>
<tr><td>6</td><td>Cross-cutting agricultural policies</td><td>5</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Policy and Planning</td><td colspan="4">3</td></tr>
<tr><td>8</td><td>Education and awareness about CC</td><td colspan="4">10</td></tr>
<tr><td>9</td><td>Resilience to CC sensitive diseases, health management</td><td></td><td></td><td>11</td><td></td></tr>
<tr><td>10</td><td>Energy security and low carbon development</td><td></td><td></td><td></td><td>9</td></tr>
<tr><td>11</td><td>Hydrometeorology</td><td colspan="4">4</td></tr>
<tr><td>12</td><td>Irrigation</td><td>3</td><td>2</td><td></td><td></td></tr>
<tr><td>13</td><td>Flood and drought protection</td><td>1</td><td>3</td><td></td><td></td></tr>
<tr><td>14</td><td>Coastal protection</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>15</td><td>Transport infrastructure resilience</td><td></td><td>3</td><td></td><td></td></tr>
<tr><td>16</td><td>Low carbon transport systems</td><td></td><td></td><td></td><td>8</td></tr>
<tr><td>17</td><td>Proofing rural infrastructure and private finance</td><td></td><td>6</td><td></td><td></td></tr>
</table>

		Type of Loss and Damage			Mitigation
		Loss of income	Damage to assets	Labour Productivity	
18	Rural awareness of CC in village development	3			
19	Gender CC resilience	7			
20	Disaster reduction management	4			
21	Sub-national disaster management capacity	4			
22	Awareness for disaster reduction	3			
Cambodia CC Strategic Plan (2013) - strategic objectives		**Number of Strategies**			
1	Improved food, water and energy security	5	2		3
2	Reduce sectoral, regional, gender, health vulnerability	11		1	
3	Climate resilience of critical ecosystems	4			
4	Low carbon sustainable development				6
5	Capacity, knowledge and awareness	13			
6	Adaptive social protection and participatory approaches	6			
7	Institutional strengthening and coordination	5			
8	International participation	5			

Table 13 summarises Table 12 and compares the number of actions and expenditure in the CCAP with the level of L&D by type. The relatively low attention paid to protecting labour productivity from CC may reflect the fact that most of the expenditure required to protect labour productivity will come from the private sector. The balance in expenditure devoted to the other two sources of L&D (ie loss of income and damage to assets) roughly matches to the level of L&D, with expenditure on damage to assets being 1.66 times higher than on loss of income and the level of L&D being 1.53 times higher.

TABLE 13 Comparison of Actions and Expenditure in CCAP with L&D

Purpose of Action	Actions in CCAP	Costs in CCAP	% L&D	Comments
Adaptation actions				
Reduce loss of income	41	31%	17%	Large number of smaller actions
Reduce damage to assets	25	51%	26%	Large roads/irrigation proofing actions
Protect labour productivity	11	6%	57%	Most expenditure by private sector
Mitigation actions	19	8%	-	
'Soft' cross-cutting actions	22	4%	-	Information, studies, capacity …

Labour Productivity

The CEGIM analysis suggests that over half the L&D is derived from reduced labour productivity. The INDC, CCAP and CCCSP all address the need to provide increased health care for climate sensitive diseases, which accounts for about 5% of total CC expenditure in the CCAP. However, the three CC strategies give very little attention to the effect of heat stress on labour productivity and none of the actions address this concern directly. This is probably because the evidence on heat stress and labour productivity is only recently becoming available. But the lack of attention in public CC policy may be caused by the fact that much of the expenditure to reduce the effects of heat stress will be undertaken by the private sector. The CEGIM analysis shows that policies to protect labour productivity from heat stress should feature amongst the highest priority adaptation actions. International work on adaptation to heat stress is still evolving, but options might include the following policies.

- **A.** reducing the need for heavy manual work to be done at periods of heat stress in agriculture, livestock, fisheries and forestry, through the use of mechanisation, new techniques and changes to enterprise and crop mix
- **B.** changes to working practices on construction sites to plan work schedules to match the level of effort to temperature, as far as possible
- **C.** improved working conditions in factories and offices (eg ventilation, breaks for rest, cooling and rehydration during periods of peak heat stress ...)
- **D.** more flexibility in working hours during periods of extreme heat
- **E.** improved information and understanding amongst managers and employees about the risks of heat stress and need to adjust working practices
- **F.** improved weather forecasting and warning systems so that managers can plan work schedules to minimise heavy workloads during expected heatwaves
- **G.** assistance with strategic business planning to make supply chains and overall profitability more resilient to heat stress

None of the above list of policies involves major direct investments from government and much of the costs will be borne by the private sector, motivated by protecting labour productivity and commercial profit. However, the government may need to devote significant funds to soft support, including services offering information and advice. It is also likely that there would be strong returns from introducing policies that involve incentives to provide a temporary highlight to companies about the need to plan for increased heat stress. Given the seriousness of the issues, this is likely to require a broad-ranging programme of incentives, including grants and financial and tax incentives. Although this may not involve the levels of expenditure required for major public investment projects, the costs are significant and urgent work needs to be done to scope a programme of policies and incentives, including building the capacity of public institutions to provide information and manage incentives.

Damage to Infrastructure

Damage to infrastructure from extreme events and sea level rise has a significant impact on economic activity across many sectors and is often the most visible impact of CC. It is important for all sectors of the economy and is the largest source of L&D for the large service sector, which depends on the ability to transport goods and services efficiently. The CEGIM analysis suggests that it accounts for about a quarter of total L&D, of which two thirds comes from sea level rise and one third from storms and floods. The INDC, CCAP and CCCSP include the following key adaptation policies related to reduced damage to infrastructure.

- **A.** Inland flood protection dykes and drainage infrastructure will prevent damage to major irrigation infrastructure and in-field irrigation facilities managed by farmers, as well as to urban areas. In the CCAP, the majority of this expenditure is integrated into irrigation investment, which is the largest single action accounting for about a quarter of all CC related expenditure. This investment is roughly matched with the large potential damage to agricultural assets included in the CEGIM analysis.
- **B.** Investment in resilient transport infrastructure is the second largest action in the CCAP and accounts for over 20% of total proposed CC related expenditure. This roughly matches the large damages

expected to be incurred from disruption to the transport system, which affects all sectors and is the largest source of damage from flooding.

C. The CCAP includes a range of actions related to rural infrastructure and disaster management. The largest of these are related to water supply and community based disaster management. Although these are important for communities at risk, they are relatively small in total and account for only about 4% of total CC expenditure in the CCAP.

D. The CCAP includes only two actions related to sea level rise, both of which are small, and the CCCSP refers only to protection of coastal ecosystems. The INDC includes coastal protection as one of the 13 priority actions. The evidence from the DARA Climate Monitor used in the CEGIM analysis suggests that damage from sea level rise will be large and that a high priority should be given to elaborating actions for protection against sea level rise.

The conclusions on damage from storms and floods are based on the costs identified in the post disaster needs assessment (PDNA), which may understate the full extent of damage perhaps because they are dependent on field surveys that will miss some impact. This could happen because it is logistically impossible to cover all impact or because some types of impact are excluded, if they are not considered relevant for government compensation and reconstruction activity. The extent to which PDNAs capture full damage needs to be reviewed. If this review work confirms that damage to infrastructure is smaller than loss of income and reduced labour productivity, then actions to introduce proofing from damage will need to be prioritised on the basis of the cost-effectiveness of the actions, to ensure that they compete with other adaptation options and do not claim too large a share of total CC expenditure.

Loss of Income

More than half of the CCAP actions that are directly related to adaptation are devoted to protection from loss of income. These actions account for about 31% of expenditure. This is roughly consistent with the relative importance of loss of income, compared to damage to infrastructure. The INDC, CCAP and CCCSP include the following key policies to protect against loss of income.

A. Strong attention is given to a wide range of actions in all the agricultural sub-sectors, with a particular emphasis on crops. This is consistent with the fact that loss of income is concentrated in these sectors.

B. The description of actions related to irrigation and coastal protection suggests that, for most of these actions, the primary motivation is to protect incomes in the areas at risk, rather than to reduce damage to assets, although the distinction between the two is not always clear and some of the actions are focused on proofing assets from damage.

C. Many of the ‘soft’ actions related to information services, studies and capacity building are relevant to all types of L&D but appear to be focused primarily on building resilience, especially to livelihoods, to minimise the loss of incomes from CC.

The Role of Agriculture

Most economic strategies assume that growth in agriculture will be slower than in industry and services. CEGIM projections are consistent with this because: a) the sector production functions are calibrated on historical patterns in which growth in agriculture has been slower than the national average; and b) the headline CEGIM scenario assumes that growth in capital and labour productivity in agriculture will be slower than in other sectors, which reflects past trends in productivity. However, disaggregating into the four agriculture sectors (ie crops, livestock, fisheries and forestry) suggests that the situation is more complex. In particular, crop production has grown at 6.3%, which is close to the national average growth of 6.8% and labour productivity in crop production has grown slightly faster (4.0% per year) than the national average (3.1% per year). In addition, investment levels in agriculture are relatively high, although this could be explained because some types of investment (eg in agribusiness) could be classified as agricultural, when they would be covered by manufacturing in national accounts.

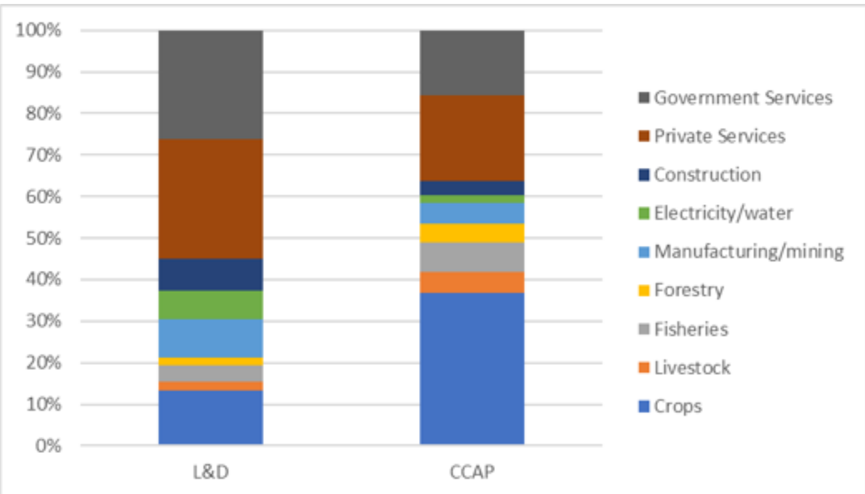
The relatively strong performance of crop production in the Cambodian economy suggests that caution should be taken in assuming that agriculture will inevitably grow more slowly than other sectors. The latest FAO review of the prospects for global agriculture gives mixed prospects, with many significant challenges (FAO 2017). However, the evidence from the last ten years suggests that there could be periods when global food prices are high, not least because of CC and poor rainfall in major crop producing areas. Countries that are able to adapt and protect themselves from these CC risks could see significant gains in agriculture. Whilst Cambodian agriculture is vulnerable to CC, it may also have more adaptation options for improved water management than some major crop exporters.

Sectoral Balance

In theory, the sectoral balance of adaptation should be guided by the sectoral balance of L&D, although the relationship between the two should not be directly proportional as there may be better opportunities for effective adaptation in some sectors with lower L&D. In practice, there are a number of technical challenges in comparing sectoral L&D with sectoral adaptation expenditure[22].

Figure 17 compares sectoral L&D with sectoral adaptation expenditure, as contained in the CCAP presented in the CCFF. The figure suggests that about 35% of CCAP expenditure is devoted to crop production (of which about two thirds is the crop production share of irrigation spending), whilst the L&D for crop production is less than 15% of total L&D. It would not be correct to conclude directly that adaptation expenditure should shift from crop production to other sectors, but the analysis does suggest that the adaptation benefits of irrigation need to be clearly estimated to justify allocating such a high share of total adaptation expenditure to irrigation. The opposite situation applies to services, which have higher L&D and lower adaptation expenditure under the CCAP. Most of the L&D in services is accounted for by damage to roads and by reduced labour productivity. The CCAP attention to roads roughly matches the L&D to roads, so the shortfall in adaptation actions relates mainly to the failure of the CCAP to address the need to limit the effects of heat stress on labour productivity.

FIGURE 17 Sectoral Balance of Adaptation Actions and Loss and Damage



[22] *In particular, significant elements of both L&D and adaptation expenditure relate to assets that affects several sectors, including irrigation, flood protection and roads. CEGIM addresses this by assuming that the proportion of the benefits from these assets follows the same pattern as assumed for depreciation.*

Mitigation and Development. Much of the international modelling work on climate change and economic growth has been done at a global level and has explored the optimal level of resources to be devoted to mitigation. At a national level, it is difficult to assess optimal levels of mitigation, since mitigation benefits are pooled globally. However, National Determined Contributions (NDCs), under the Paris Agreement, provide a basis for defining a strategic framework for achieving mitigation targets. Some mitigation frameworks (eg in Indonesia) simply estimate the Marginal Abatement Costs (MACs) of mitigation programmes and find the least cost combination of programmes needed to deliver on the NDC. In practice, there are many 'win-win-win' programmes that contribute to mitigation but also have a net positive contribution to development (ie have a negative MAC) and some adaptation benefits (eg energy efficiency, public transport and the 'fourth industrial revolution'). The CEGIM analysis provides an opportunity for taking this analysis a step further and estimating the way in which such programmes may affect economic growth, including future investment and labour productivity and the changing balance of sectoral activities.

6.2 Integrating CC into Planning and Budgeting

Monitoring L&D Evidence

The CEGIM projections are strongly influenced by the evidence on L&D and this evidence should be monitored and updated on a regular basis. The Ministry of Environment (MoE) should take the lead in providing the latest evidence on L&D, by sector and type of L&D, so that MEF can update the CEGIM analysis. This is likely to involve only modest adjustments to projections, since most key parameters are calibrated using a triangulation from several sources, most of which will not change. However, it will be important to keep track of whether the latest evidence suggest a slight hardening, or softening, of the expected impact.

Monitoring Economic Trends

The CEGIM projections are strongly influenced by recent economic data, which determines the calibration of production functions and trends in labour and capital productivity. Ideally, the calibration should be updated regularly to reflect the latest data. This is likely to involve only modest adjustments to the projections, but the direction and scale of these adjustments is important, both for the confidence it gives to the projections and for the way in which it is likely to raise questions about new features that need to be incorporated in the analysis.

Macroeconomic Projections

The macroeconomic projections used by MEF for macroeconomic policy could be adjusted to take into account the likely impact of CC on economic growth. In the short term, this impact is relatively small, but small impacts are important for fiscal projections, especially when dealing with risks that can vary from year to year. The CC impact projected by CEGIM could be added to the existing econometric model as a factor that adjusts the estimate provided by the model (ie, using the results presented in this paper, GDP would be 0.4% lower in 2020). Alternatively, as an initial and more cautious step, it would be possible to include the CEGIM projections as one additional variable, with a suitable weight.

Planning Strategies

The NSDP and new Rectangular Strategy could recognise the nature and severity of the CC threat to economic growth and give some orientation about whether the policy response needs to be expanded. This could include some prioritisation amongst the main policy response options, which are: improving the way CC is considered in the design of programmes; diverting some additional funds to programmes that address adaptation; and introducing incentives, regulations and information services to encourage more private sector adaptation.

Climate Change Impact Assessment

Cambodia already has an impressive range of evidence from CCIA work in all key sectors affected by CC. Guidance on project preparation could include requirements for explicit analysis of how CC is likely to affect the net benefits and, hence, the contribution that projects can claim to make to protecting Cambodia's economic growth from the risks related to CC. This could focus on the potential for win-win-win gains, for actions that promote development, adaptation and mitigation benefits, but could add the challenge to provide evidence on the relative importance of each of the benefits.

International Reporting

Cambodia's reporting on NDCs under the Paris Agreement should include a statement of the expected impact of CC on economic growth and an update on the latest evidence about the expected effectiveness of NDC policies in reducing the full economic impact of CC.

Further Work

Further work is required on the following issues:

- refining all evidence relating to the three types of L&D and how they affect each sector, with particular reference to understanding whether reductions in income affect the whole sector
- disaggregating the policy response, to give some orientation to priorities for adaptation expenditure (eg according to the three types of L&D, to economic sectors or to types of policy response)
- work on potential changes in capital and labour productivity over the longer term, which should enable a Cobb Douglas function to be used more reliably
- the timing of adaptation investment and matching this to the timing of CC economic impact and the timing of policies related to emergency response and contingency financing
- exploring the nature of savings and investment within key sectors to understand better the indirect impact of a drop in GDP in one year on savings and investment and how this might be affected by the nature and size of the drop in GDP
- extending the CEGIM analysis to consider years of extreme CC shocks and exploring how policies to deal with fiscal risks (eg contingency funds, emergency borrowing and supplementary budgets) can limit the impact of extreme shocks to one year
- conducting further analysis of the social implications of CC (ie on poverty, inequality, gender, disability, health and human development), but within the context of an economic model that recognises the economic value of protecting society from CC

The CEGIM model runs on a single worksheet, with about 200 rows. However, it also has quite a wide range of supporting worksheets and has become more detailed than was originally expected, because of the desire to include additional features like: various different sources of evidence on investment; the scale and effectiveness of adaptation expenditure; scenarios to explore different assumptions; income distribution; and the ability to change the production function. Although the worksheet is transparent, it has now become quite detailed, and care will be required to make further developments without disrupting the integrity of the analysis. The model would now benefit from some streamlining and clarification to make it easier to change and adjust, without risk of disrupting its integrity.

GLOSSARY

Adaptation Benefit

The reduction in L&D caused by an adaptation programme, which may happen directly or more indirectly through improved resilience of institutions, societies or ecosystems.

Adaptation Benefit Cost Ratio

The total adaptation benefits divided by total costs of a programme.

Adaptation Gap

The proportion of the expected economic impact that is not addressed by currently planned adaptation expenditure and policy.

Calibration

The process of defining the relationships in the model, based on the best evidence available.
CC Relevance. This term is used in different ways to refer to the relative importance of adaptation or mitigation, compared to routine development. It is usually assessed either in terms of explicit and/or implicit objectives and sometimes or in terms of expected benefits.

Cobb Douglas

A production function that assumes constant elasticities. The Cobb Douglas function takes the form Y = a.K^b.L^c and is calibrated using the log form of the equation, In(Y) = In(a) + b.In(K) + c.In(L).

Elasticity

The % in a dependent variable (eg GDP) divided by the % change in and independent variable (eg K or L).

Endogenous/dependent variable

A variable that is determined by the model, based on the relationships defined in the model and the levels of the exogenous/independent variables.

Exogenous/independent variable

A variable that is determined by evidence outside the model and is not affected by the model behaviour.

Factor productivity

The change in GDP divided by change in either K or L.

Loss and Damage

The total impact of CC on society, including losses to income and damage to assets, which may be defined narrowly in terms of infrastructure or more broadly to include institutions, human capital and environment.

Perpetual Inventory Method

The method of estimating capital assets by assuming that assets at the end of the year are equal to assets at the start plus investment less depreciation.

Resilience

The extent to which institutions, societies or ecosystems are likely to reduce L&D in the future.

Total Factor Productivity

The change in GDP divided by a weighted total of K and L. This is usually done with K usually having a weight of 25% and L 75%, but the Cambodia calibration suggests that the appropriate weights for Cambodia are about 50:50.

BIBLIOGRAPHY

ADB (2009). "The Economics of Climate Change in Southeast Asia: A Regional Review."

ADB (2014). "Cambodia Country Poverty Analysis."

Addison, D. (1989). "The World Bank Revised Minimum Standard Model."

Ahmed, M. and S. Suphachalasai (2014). "Assessing the Costs of Climate Change and Adaptation in South Asia."

Berlemann, M. and J.-E. Wesselhöft (2017). "Aggregate Capital Stock Estimations for 122 Countries: An Update." Review of Economics 2017; 68(2): 75–92.

Bun, N. P., S. Nam and P. Degen (2014). "Potential Impacts of Climate Change on Fisheries in LMB." Presentation at the Second Mekong CC Forum.

Chea, S. and A. Sharp (2015). "Flood Management in Cambodia: case studies of flood in 2009 and 2011 ".

Climate Scrutiny (2017). "Estimating Full Economic Loss and Damage: Practical Guide."

DARA and Climate Vulnerability Forum (2010). The State of Climate Crisis: 2010 Report on the Climate Vulnerability Initiative. http://daraint.org/wp-content/uploads/2010/12/CVM_Complete-1-August-2011.pdf.

Dietz, S. and N. Stern (2015). "Endogenous Growth, Covexity of Damage and Climate Risk: how Nordaus' Framework Supports Deep Cuts in Carbon Emissions."

Dunne, J. P., R. J. Stouffer and J. G. John (2013). "Reductions in labour capacity from heat stress under climate warming." Nature Climate Change 3: 563.

EIC (2009). "Cambodia Economic Watch."

Ernst and Young (2016). "Worldwide Capital and Fixed Assets Guide ".

FAO (2017). "The Future of Food and Agriculture: Trends and Challenges."

GoI (2007). "Rates of Depreciation."

Hope, C. (2011). "The PAGE09 Integrated Assessment Model: a Technical Description."

IMF (2007). "The System of Macroeconomic Accounts Statistics: An Overview."

IMF (2017). "World Economic Outlook. Chapter 3. The effects of weather shocks on economic activity: how can low-income countries cope?".

IPCC (2000). "Special Report on Emissions Scenarios."

IPCC (2012). "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Summary for Policy Makers."

IPCC (2014). "Fifth Assessment Report: Summary for Policy Makers."

Kamps, C. (2006). "New Estimates of Government Net Capital Stocks for 22 OECD

Countries 1960-2001." IMF Staff Paper 53 (1), 120–150.

Kjellstrom, T., B. Lemke, M. Otto, O. Hyatt, D. Briggs, C. Freyberg, L. Hasson and L. Lines (2016). "Climate Change Health Impacts and Prevention Report, Climate-CHIP for Cambodia."

MDBs (2015). "Joint Report on Multilateral Development Banks' Climate Finance."

Ministry of Finance (2014). "Bangladesh Climate Fiscal Framework."

MoE (2015). "Cambodia's Second National Communication: submitted under the UNFCCC."

MoE (2015). Cambodia Climate Change Financing Framework.

Mokoro (2010). "Cambodia Agriculture, Irrigation and Rural Roads Public Expenditure Review."

NBC (2016). "Report on Foreign Direct Investment Survey Results 2014."

NCDM (2016). "Understand the Past, Save the Future." Analysis Report Cambodia Disaster Loss and Damage Information System.

NCSD (2016). "Promoting Private Sector Contribution to the Climate Change Respones in Cambodia."

NIS (2014). "Cambodia Socio-Economic Survey 2014."

Nordhaus, W. and J. Boyer (2000). "Warming the World: Economic Models of Global Warming."

OECD (2011). "Handbook on the OECD-DAC Climate Markers."

Pearce, D. W. (2001). The Economic Value of Forest Ecosystems.

RGC (2010). "Cambodia Post-Ketsana Disaster Needs Assessment ".

RGC (2014). "Cambodia Post-Floods Early Recovery Needs Assessment Report."

RGC (2015). "Cambodia's Intended Nationally Determined Contribution."

RGC (2015). "Public Investment Programme 3 year Rolling 2016-2108."

Stern, N. (2006). "Stern Review on The Economics of Climate Change."

Tol, R. (2002). "Estimates of the Damage Costs of Climate Change."

UNDESA (2016). "World Economic and Social Survey: Climate Change Resilience: an opportunity for reducing inequalities."

UNDP (2015). "A Methodological Guidebook: Climate Public Expenditure and Institutional Review (CPEIR)."

UNDP (2016). "Climate Change and Labour: Impacts of Heat on the Workplace."

UNDP (2017). "Hard Choices Integrated Approaches: a Guidance Note on Climate Change Financing Frameworks."

USAID (2013). "Mekong ARCC Climate Change Impact and Adaptation Study."

USAID (2014). "Climate Change in the Lower Mekong Delta: an Analysis of Economic Values at Risk."

World Bank (2017). "Cambodia - Sustaining strong growth for the benefit of all." Washington, D.C. : World Bank Group.

World Bank (2017). "Disaster Risk Finance Country Diagnostic Note: Cambodia."

World Bank, GFDRR and ISDR (2012). "ASEAN: Advancing Disaster Risk Financing and Insurance in ASEAN Member States: Framework for Implementation - Technical Appendices."

Yamamura, E. (2013). "Impact of natural disasters on income inequality: Analysis using panel data during the period 1965 to 2004."

Younas, M., K. Ishaq and I. Ali (2014). "Effect of Climate Change on Livestock Production in Pakistan."

ANNEX 1

Loss and Damage

A1.1 Exposure to CC Risks

The starting point for estimating the impact of CC on economic growth is to understand the exposure of Cambodia to CC risks. The CEGIM model distinguishes between 6 types of risk: flood, drought, storm, more variable rainfall (including less predictable seasons), heat and sea level rise.

The main source of evidence for disasters in Cambodia is the NCDM Analysis Report which reports on the results of the Cambodia Disaster Loss and Damage Information System. The last version of which covers the period of 1996 to 2013.

BOX 5 IPCC Climate Change Scenarios

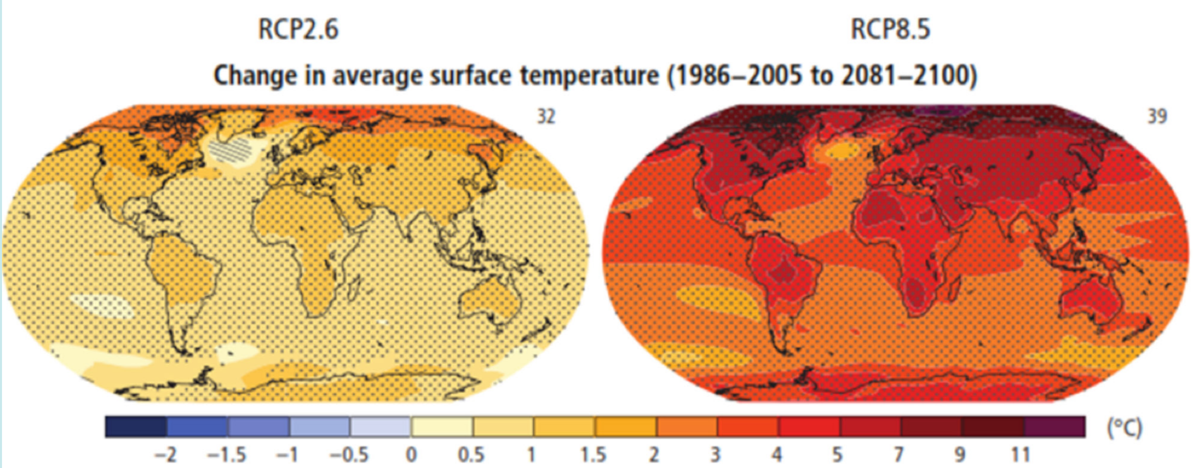
The IPCC's Fifth Assessment Report (AR5) uses four main CC scenarios: RPC8.5, RCP6.0, RCP4.5 and RCP2.6. RCP refer to the 'Representative Concentration Pathways' and the numbers refer to the increase in net insolation, measured in Watts per square metre. RCP8.5 is considered the worst case scenario, with little mitigation, and has an increase in global mean temperature of 2.0oC +/-30% by 2055. The RCP2.6 scenario reflects the best case target of the Paris Agreement and has a rise in temperature of 1.0 +/-60% by 2055. The other two scenarios are intermediate, with the temperature increase and range of uncertainty roughly proportional to the pathway concentration numbers. Projections from 2050 to 2100 are roughly linear.

The RCP scenarios in AR5 replace the scenario system introduced in 2000 and used in AR3 and AR4 and defined by the Special Report on Emissions Scenarios (SRES). The SRES system identified 4 main scenario families: A1, A2, B1 and B2. The letters refer to the degree of coordinated control of emission (with A being better than B) and the numbers refer to the extent to which public policy gives priority to environmental and CC issues. The expected temperature changes are as follows, in order of severity of CC: B1 is 1.1 to 2.9oC; B2 is 1.4 to 3.8; A1 is 1.4 t 6.4; and A2 is 2.0 to 5.4. The four scenarios are therefore quite similar to those in AR5, although they involve slightly higher levels of temperature rise.

The IPCC scenarios provide an international standard for average global change. AR5 also provide the following map, which suggests how the average temperature change is likely to vary around the globe, which suggests that change in Cambodia could be significantly more severe.

Source: (Climate Scrutiny 2017)

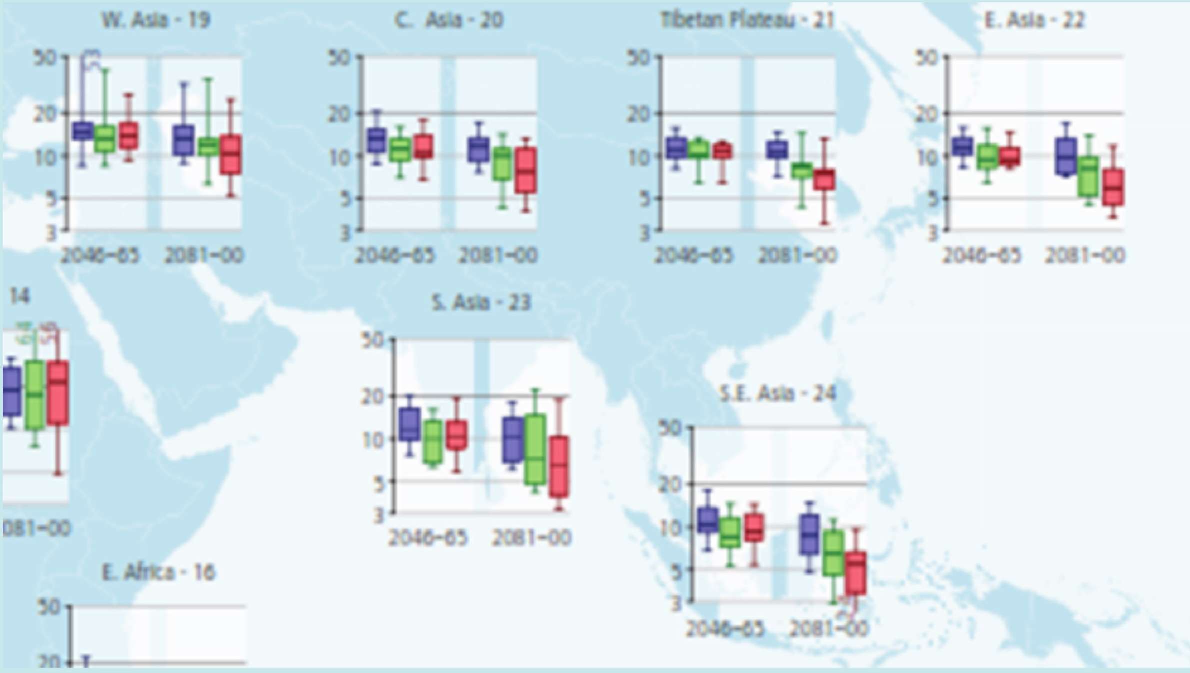
FIGURE 18 Global Variation in Rise in Temperature



Source: (IPCC 2014)

The second major dimension of exposure to CC is in the changing frequency of extreme events and rainfall variability. The evidence on this from climate models is less clear, especially at a local scale, where topology and maritime systems can have a large influence. However, some broad indication is provided by the IPCC 2012 Special Report on Extreme Events (SREX). This looked at changes in the frequency of floods and droughts in 26 regions of the world. For SE Asia, the figure below shows that the SREX analysis suggests that floods that currently have a 20 year return period will have a return period of between 9 and 11 years in 2045-2065, depending on the IPCC CC scenario (blue is B1, green is A1B and red is A2). Other indicators of rainfall variability (eg drought and storm frequency and changes in seasonality) are likely to change roughly in line with flood frequency.

FIGURE 19 Changes in the Frequency of Floods



Source: (IPCC 2012)

Flood

There are various sources of evidence on the history of flooding in Cambodia.

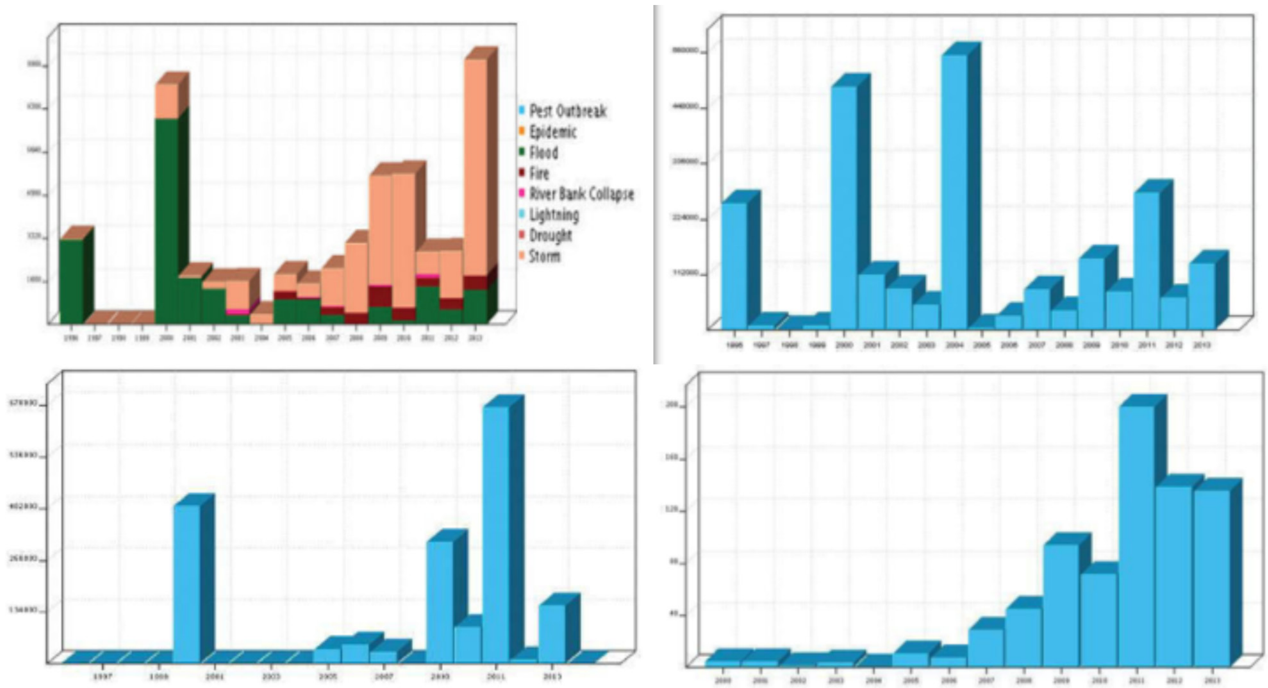
FIGURE 20 Flood History in Cambodia

1996	Sep: C/S provinces
1999	Aug-Sep: 5 provinces in S/W/E
2000	Jul-Sep: 21 provinces, 3m people, 2600km mains roads, 30 bridges, 1000 schools, 170 health centres
2001	Aug: all provinces along Mekong
2002	Aug: 11 provinces, Prey Veng worst
2006	Aug: all provinces along Mekong
2009	Sep typhoon: 11 provinces in C, widespread damage to houses, infrastructure & agriculture
2011	Oct: 18 provinces, 1.2m people, 247 deaths, 52K housedholds evacuated
2013	Sep: 20 provinces, 188 deaths, 45K people

Source: from (Chea and Sharp 2015)

The National Committee on Disaster Management (NCDM) reports a range of figures for the impact of a range of disasters affected by CC (ie flood, storm, drought, lightening, fire, river bank collapse) on a range of variables (ie loss of life, damage to housing, loss of crop production, damage to roads).

FIGURE 21 Sources of Loss and Damage from the Cambodia Disaster Information System



Source: (NCDM 2016)

A1.2 Impact on Economic Output

Agriculture

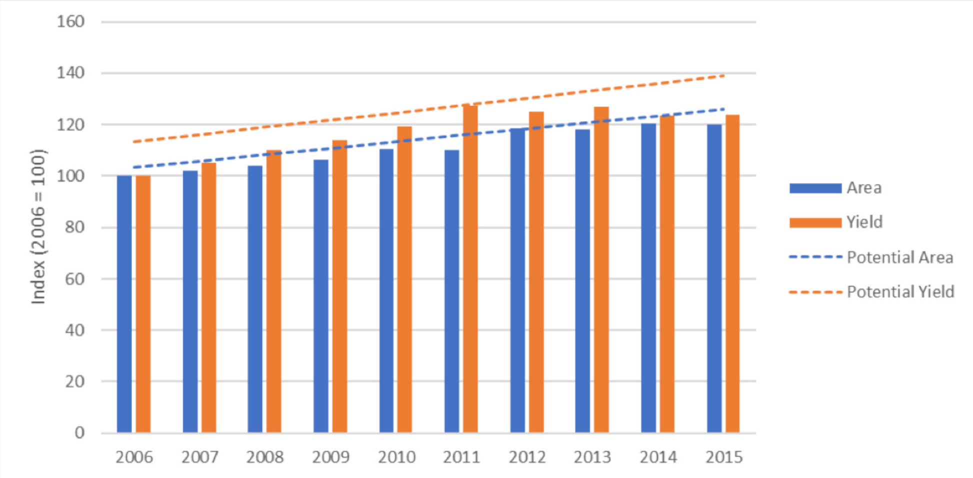
There are several different dimensions to potential impact on agriculture, including: the routine annual losses arising from poorly distributed and unpredictable rainfall patterns; the losses of whole crops from major flooding, drought and storms; and the possibility that increases in temperature will reduce yields in some crops, requiring farmers to switch to less profitable crops.

There has been little analysis of the impact of routine variations in rainfall patterns and increase in temperature. The Cambodia 2010 Agriculture PER suggests that dry season crop margins will be most affected by seasonality and could be as much as 20% lower with CC (Mokoro 2010). The CCFF estimated that the loss from rainfall variability could increase by an amount equivalent to 0.28% of GDP by 2050. The USAID Mekong ARCC study used a crop modelling approach and concluded that rice yields are likely to decrease by 3% in Mondulkiri and 3.6% in Kampong Thom, while maize yields would decline by 6% in Kampong Thom (USAID 2013). The ADB 2009 study for SE Asia estimated the potential rice yield could decline by as much as 50% by 2100, using the most serious CC scenario, with a 5oC increase in temperature (ADB 2009). As this impact is roughly proportional to temperature rise, a CC scenario with an increase of temperature of 1oC in 2050 would suggest a yield reduction of about 10%.

The L&D in agricultural production arising from increased frequency and severity of floods, droughts and storms is likely to be higher than the L&D from an increase in routine variability of rainfall. The Agriculture PER estimates that the average annual loss of rice yields arising from poor rainfall distribution is about $80m. The Post Flood Early Recovery Needs Assessment (PFERNA) suggested that agricultural losses were about USD 152m for the 2013 flood and USD 56m in the 2009 typhoon (RGC 2010, RGC 2014). Similar losses can be expected from other crops. The CCFF estimated the value of this L&D would increase by an amount equivalent to 1.14% of GDP by 2050.

In theory, the net effect of all these dimensions should be captured in the data on area harvested and yields. Both area and yield show a steady upward trend, which reflects progress in adding new area to cultivation and in improved farming practices. This includes the effects of investment in land improvement and in farm equipment. Figure 22 presents the area and yield over the last 10 years, along with lines that present the potential area and yield. These lines of potential area and yield are estimated by using regression analysis to obtain the average increase per year in area and in yield over the period. It is then assumed that the years with the highest area and yield represent the achievement when weather conditions were the best for rice during the period. The lines of potential area and yield are then adjusted to pass through the level achieved in these optimum years. The difference between the potential and actual area and yield reflects the losses over the period. There could be several reasons for these losses, including economic and social factors, but these factors are more likely to affect the general trend than to reflect annual variations and the main reason for the annual variations is likely to be the weather. The average loss and damage arising from below potential area harvested is 3.2% and the average loss and damage arising from below potential yield is 6.7%. The loss and damage is multiplicative and is therefore 10.1%. The current agriculture share of GDP is 16%, suggesting L&D increasing by about 1.6% of GDP, which is roughly consistent with the CCFF estimates. However, it is likely that the agriculture share of GDP will fall over the next few decades, so the L&D when expressed as a % of total GDP is likely to be smaller.

FIGURE 22 Rice Area and Yield



Source: MAFF Annual Reports

Fisheries

The impact of CC on fisheries is complex, because the response of aquatic ecosystems is specific to each system and is difficult to model (USAID 2013). There seems to be good agreement that many fisheries ecosystems will change markedly as water temperatures change, with consequent changes throughout the ecosystem (Bun, Nam et al. 2014). In particular, there are fears that climate variability the process of change is likely to lead to instability in species numbers, making fishing practices difficult to manage. Modelling work is less common than for crops, and the results are less easily transferable from one ecosystem to another. However, one study on the north coast of Java suggested productivity could decline by as much as 80% as a result of climate variability. The USAID Mekong ARCC study suggested that the impact of CC on aquaculture productivity would probably be negative, but did not provide estimates of how serious this would be. CEGIM includes an assumption that production reduces by 1%. This is intended to be a 'placeholder' to be refined if and when evidence becomes available.

Forestry

The evidence of the impact of CC on forestry is also specific to each ecosystem. It seems clear that there will be significant changes in forest biodiversity, but the change in productivity of forestry in providing value added to the economy is less clear. There is some evidence that, in certain conditions, forests could become more productive, in terms of biomass production per hectare. The USAID Mekong ARCC study suggested that, on balance, there would be a decline in forest productivity, due to dry season drought and wet season flood and soil saturation (USAID 2013). The study was not, however, able to put a figure on this decline. The ADB 2009 study for SE Asia suggested that forest productivity could decline very seriously with the higher CC scenarios, with some tropical forests being slowly replaced by much less productive shrubland. CEGIM assumes that there is a small 1% drop in forest value added. This is intended to be a 'placeholder' assumption to be refined if and when evidence becomes available.

Forests provide many benefits that are not easy to quantify and are not included in national accounts. These include: soil moisture retention, reducing flooding and siltation downstream; improved water quality; recreation, leisure and health benefits; fuelwood; carbon sequestration; and biodiversity. There is substantial international work to provide estimates about the value of these benefits, which typically suggests that total non-market forestry benefits are several times more valuable than the value of sustainable timber extraction (Pearce 2001). The vulnerability of these benefits to CC is also likely to be similar to the vulnerability of timber extraction as both are related to biomass productivity. However, these non-market benefits are not included in this analysis in order to retain clarity in the headline conclusions.

Energy

Losses in the energy sector take the form of reduced hydroelectric power generation, higher cooling costs, higher losses in transmission and damage to infrastructure from extreme climate events. The CCFF estimated that electricity production amounted to about 5000 GWh/year, worth about $500m. About $15m of this comes from hydropower, which will be strongly affected by rainfall patterns. Based on international evidence, total losses during transmission are typically about 10%, which would be worth $50m and these are affected by storms and by temperature. The costs of cooling in thermal power generation also increase with temperature. Surprisingly, there is little international evidence of the potential magnitude of the L&D associated with electricity generation and distribution. The CCFF assumed that the additional L&D associated with CC will be about $10m, or 2% of the value of generation. This was 0.07% of GDP in 2010, but is likely to increase sharply as energy's share of GDP increases. The consultation undertaken by CEGIM will be able to check and refine these assumptions.

Sea Level Rise

Flooding and salinization arising from sea level rise and abandonment of some coastal areas. Further research is needed to obtain evidence of possible L&D arising from sea level rise in Cambodia. CEGIM relies on the estimate for Cambodia in the DARA 2010 Climate Monitor report (DARA and Climate Vulnerability Forum 2010). The DARA report includes some much higher estimates for the costs of sea level rise in 2030 but CEGIM uses the lower estimates for 2010 because the basis of the estimates is not clear and, where there are doubts over assumptions, CEGIM opts for conservative assumptions that minimise the risk of overstating the impact of CC.

A1.3 Impact on Health and Labour Productivity

There are two main elements of impact on health: increased occurrence of diarrhoea and other climate sensitive diseases and increased heat stress. The most common method of valuing health impacts is through the use of Disability Adjusted Life Years (DALYs). Cambodia does not yet have a planning yardsticks for the value of a DALY, but the WHO guideline is three times per capita GDP.

Climate Sensitive Disease

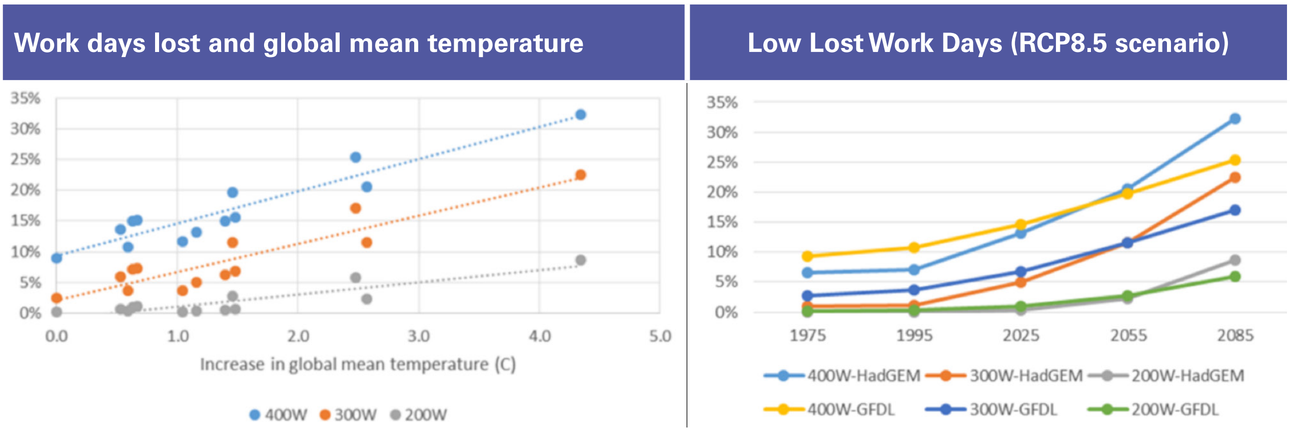
Climate sensitive diseases include most of the major water-borne diseases, of which the most important is diarrhoea, and diseases that are affected by heat, including cardiovascular and respiratory diseases. The CCFF reported WHO figures that suggest that climate sensitive diseases result is the loss of about 400,000 DALYs per year. WHO estimates that these could increase by 10% with CC, which suggests that the extra health burden from CC on climate sensitive diseases would be about $120m or 0.85% of GDP. The ADB 2009 CC impact study suggested that CC could increase the burden from some climate sensitive diseases by as much as 18% over 30 years.

Labour Productivity

There has been some significant international progress in research into the possible impact of heat stress on labour productivity. The results of this research have relatively high degrees of confidence, because they are based on extensive physiological and field evidence of labour productivity at different temperatures, typically using Wet Bulb Globe Temperature. The research suggests this will become the largest single source of impact of CC on economic growth (Dunne, Stouffer et al. 2013). The IPCC Fifth Assessment Report suggested that labour productivity could decline by more than 20% in the last half of the century, for sectors most affected (IPCC 2014). A recent global review by UNDP suggested that the worst case IPCC CC scenario (ie RCP8.5[23], with a 3.7oC rise), Cambodia would see an average reduction in productivity across all sectors of 6.54% by 2055 (UNDP 2016). The relationship between temperature and labour productivity is roughly linear so, if the Paris Agreement succeeds in achieving its best case objective of a 1.0oC rise, the impact on labour productivity by 2055 would be a 1.77% drop.

The same global evidence base was recently applied in more detail in Cambodia (Kjellstrom, Lemke et al. 2016), taking into account the share of employment in agriculture, industry and services, the way this share will change through the next century and the fact that the impact in outdoor activities is much higher than in indoor activities. The analysis suggested that overall loss of daylight work hours across the whole economy is 3.1% by 2055, using the RCP2.6 CC scenario, which is a relatively moderate CC scenario. Figure 23 shows the results of the analysis, including the evidence on the relationship between the loss of work days and temperature rise from 3 levels of energy, with 400W being the equivalent of hard outdoor labour (eg for agriculture and construction), 300W being other manual (eg industrial) and 200W being non-manual labour. The right figure shows the way low days increases through the century for the RCP8.5 scenario. This is the worst case IPCC scenario and the temperature rise for 2050 of the best case RPC2.6 scenario is roughly half the CRP8.5 scenario. Thus, assuming an optimistic RCP4.5 scenario, the days lost by 2050 would be about 1.3% for non-manual, 6% for manual and 10% for intensive manual work.

FIGURE 23 Lost Work Days from T emperature Rise



Source: (Kjellstrom, Lemke et al. 2016)

A1.4 Damage to Infrastructure

Public Infrastructure

The L&D in the public sector is composed mainly of more rapid degradation of national and rural roads, irrigation, water and sanitation and flood protection infrastructure. Some L&D to public sector buildings will also happen. These losses can be reduced by higher spending on maintenance and adaptation.

[23] *The IPCC's Fifth Assessment Report uses four main CC scenarios: RPC8.5, RCP6.0, RCP4.5 and RCP2.6. RCP8.5 is considered the worst case scenario, with little mitigation, and has an increase in global mean temperature of 2.0oC +/-30% by 2050. The RCP2.6 scenario reflects the best case target of the Paris Agreement and has a rise in temperature of 1.0 +/-60% by 2050. The other two scenarios are intermediate, with the change and range roughly proportional to the pathway concentration numbers. Projects from 2050 to 2100 are roughly linear.*

Table 14 summarises the level of public assets, by type of capital using figures for the Cambodia CCFF, which were estimated for 2010. The level of depreciation is as described in the section on deprecation in section 3.4 below. It is assumed that depreciation is strongly related to extreme climate events and that, if these double by 2050, then the level of depreciation will also double.

TABLE 14 Value of Public Assets and Increase in Depreciation

	Units	Unit cost of investment	Value of assets	Normal Depreciation	L&D[1]
Irrigation	0.8m ha	450 $/ha	$ 360m	2.1%	$ 7.6m
Roads	40,000 km	8000 $/km	$320m	4.2%	$ 13.4m
Watsan	4m people	40 $/person	$ 160m	5.3%	$ 8.5m
Flood protection	??	??	$ 100m?	3.3%	$ 3.3m
Public buildings	??	??	??	??	$ 32.8m
Total			**$940m**		**$65.6m**

[1] *Additional L&D from CC is estimated by assuming that extreme events will become twice as frequent and so double the rate of depreciation*

This increased depreciation is an estimate of the potential damage to public infrastructure, if government does not divert resources from other expenditure to cover the increased degradation of public infrastructure. However, if the deprecation is not covered by government, there will be further losses to production sectors in the economy that are dependent on government infrastructure. These are picked up in the production function for each sector, which includes an estimate of each sectors share of the main public assets. Thus, the impact of CC on public infrastructure does not contribute directly to reduced GDP, but does so indirectly through its impact on the production in the private sector.

If the government did decide to divert resources to cover the increased depreciation, then this would prevent any losses in the private sector. However, this would also have large costs than the direct costs of covering depreciation, since it would divert public funds that could be expected to deliver BCRs of at least 2.0 and these benefits would be lost.

Private Infrastructure

Flood damage is likely to lead to increased loss of life and injury, and damage to urban and rural and urban property, arising from more frequent and severe storms.

- The SNC estimates that damage from floods was $157m in 2000, $30m in 2001 and $12m in 2002, excluding loss of life and injury (MoE 2015).
- The Mekong River Commission flood damage analysis estimated the average damage to infrastructure in three districts between 2000 and 2007 was 2.5 $/person/year, suggesting a national total of about $35m, or 0.25% of GDP .
- The Post Flood Early Recovery Need Assessment Report (PFERNA) for the 2013 flood estimated the total cost of the 2013 floods as USD 356m, of which 202m was for loss (with 152m for agriculture), and 153m is for damage (with 80m for roads and 52m for water and irrigation (RGC 2014).
- The Post Disaster Needs Assessment for the Ketsana typhoon in 2009 as USD 132m, of which 74m was for losses (with 56m for agriculture and 11m for transport) and 58m for damage (with 15m for housing, 24mn for education and 14m for transport) (RGC 2010).

- The World Bank and GFDRR estimated average annual losses from natural disasters to be USD 74.2 million, or 0.7% of GDP, with floods accounting for 55%, droughts 28%, storms 4% and earthquakes 3% (World Bank, GFDRR et al. 2012).
- The Disaster Risk Finance Cambodia Country Diagnostic (DRFI) reported damage of USD 132m in the 2009, USD 625m in 2011 and USD 357m in 2014 (?). Further, the DRFI estimated average annual losses of USD 54n from floods, equivalent to about 0.7% of GDP (World Bank 2017).
- The NCDM analysis suggests that, in an average year, between 1000 and 2000 houses are lost from climate related disasters. This current level of damage is expected to double by 2050.

TABLE 15 Reports on Damage from Climate Related Disasters (USDm)

	2000 Flood	2001 Flood	2002 Flood	2009 Typhoon	2011 Flood	2013 Flood	2015/6 Drought	Average Annual
SNC	157	30	12					
PDNA/ PFERNA				132		356		
DRFI (2017)				132	625	374		54
WB/GFDRR								74

According to the NCDM figures, the main cause of loss of life from disasters comes from floods and lightening, both of which are related to CC. In each case, loss of life in a very bad year exceeds 200 people and average losses over the last 10 years are over 100 per year. Whilst it is both difficult and morally hazardous to put values on loss of life, the use of Disability Adjustment Life Years (DALY) allows this to be done to obtain some indication of the priority to be given to the challenge, compared to other related challenges . Assuming a DALY is valued at 3 times per capita GDP and the average further life expectancy of each death is 30 years, the deaths could be value at about $10m or about 0.05% of GDP.

Values at Risk Analysis

The 'Economic Values at Risk' approach provides complementary evidence and was used in the Lower Mekong Basin (LMB) (USAID 2014). This approach recognises that the impact of CC is uncertain and so focuses instead on a clear assessment of the total economic that will be affected by CC, without assessing the level of impact on each value. The 2014 analysis was for the whole LMB and it is not always easy to isolate Cambodia's share of the results, but the study identifies 5 types of impact and the values at risk for each type are:

- crop production USD 2546m for the whole LMB, with the Cambodia share unclear
- non-agricultural infrastructure services[24] USD 3427m, of which about 61% is in Cambodia
- worker productivity USD 1578m, for Cambodia, valued from the expect loss in work days
- hydropower USD 434m, but this is negligible in Cambodia
- ecosystem services USD 1241, the large majority of which is in the Mekong delta wetlands

[24] *The estimate refers to the value of services dependent on infrastructure, rather than on the capital value. The value of services was estimated as the GDP generated by the people affected by the infrastructure at risk, estimated by multiplying the number of people by the average per capita GDP in the region.*

ANNEX 2

Sectoral Investment

This annex describes public and private investment in Cambodia and presents a system for allocating 'beneficiaries' of the assets. The beneficiaries refer to the sectors of the economy whose output is determined by the level of the assets.

Total investment was based on the most recent national accounts used by MEF. These have levels of total investment that are nearly 5% higher than in the version most recently published by NIS, which were recognised by NIS as understating investment. The most recent version is similar to Vietnam at a similar stage of development.

Four elements of investment in Cambodia are assessed: public investment, bank lending for investment, foreign direct investment and reinvestment by households and enterprises. These provide an estimate for GFCF of USD 5578m in 2016, which is 27.8% of GDP.

Public Investment

Total public investment is described by development expenditure in the government accounts. In 2016, public investment amounted to 7.8% of GDP, or about USD 1672m, which was 30% of total investment. The sector shares of public expenditure are based on the NSDP 2014-2018 and the PIP 2016-2018, which better reflects the longer term balance than an individual budget year (RGC 2015). Sector shares are assumed to remain constant throughout the period because data for a long time series is difficult to obtain. The mapping of departmental expenditure to sector shares is described in the following table.

TABLE 16 Mapping of Public Investment to Sectors

	Private Assets									
	Social	MAFF crops	MAFF other	Rural MOW-RAM	Rural MRD	MIME	MPWT tran-sport	MPWT wat-san	Power	Other
PIP (% sector totals)										
Crops	0%	90%	0%	85%	18%		10%			16%
Livestock	0%		25%		5%		1%			3%
Fisheries	0%	10%	50%	5%	5%		1%			6%
Forestry	0%		25%		5%		2%			2%
Mining	0%						2%			2%
Manufacturing	0%				20%	25%	15%		33%	17%
Electricity & water	0%			5%	1%	75%	1%	50%	33%	1%
Construction	0%				5%		10%	50%	33%	12%
Trade	5%				20%		25%			10%
Hotels & restaurants	5%				5%		3%			5%
Transport & comm.	5%				10%		21%			9%

	Private Assets									
	Social	MAFF crops	MAFF other	Rural MOW-RAM	Rural MRD	MIME	MPWT tran-sport	MPWT wat-san	Power	Other
PIP (% sector totals)										
Financial sector	2%						2%			2%
Government services	75%			5%	5%		5%			1%
Real estate	5%				1%		5%			7%
Other services	2%						8%			8%
Total	100%	100%	100%	100%		100%	100%	100%	100%	100%
Share ot Total (from PIP)	32%	4%	4%	8%	4%	4%	12%	4%	4%	24%
Depreciation	5.0%	5.0%	5.0%	5.0%	4.2%	5.0%	4.2%	5.3%	5.0%	5.0%

Note: Table 6 gives 12% for rural development and the split is based on annex tables by ministry
Source: (RGC 2015) Table 6

Banks and Private Investment

Net new borrowing from the bank and micro-finance institutions was based on banking survey data provided in the NBC statistics for banks and micro-finance institutions. This gives total lending of USD 2220m in 2016, of which USD 1750m is for investment in sectors and the remainder is for consumption loans. A sectoral breakdown is available into agriculture, industry and services. The majority of investment bank investment is in the service sector, but the balance between agriculture and industry has, rather surprisingly, shifted in favour of agriculture between 2005 and 2016.

Foreign Direct Investment (FDI)

FDI data is available in total from the IMF Article IV tables, with data from 2005 to 2016 and a figure of USD 1656m for 2016, excluding FDI in the financial sector and in accommodation. This is 29.7% of total investment. The sectoral breakdown of FDI is provided in the 2014 NBC report on the survey, but is provided only for the stock of FDI for 2014 (NBC 2016). It is assumed that the sectoral shares of FDI in other years remains the same as the share of FDI stock in 2014.

Reinvestment

In addition to the above three sources of GFCF, there will also be some private sector reinvestment of profits within households and enterprises. No evidence for this is available. It is assumed to be considerably smaller than the other sources and is set at USD 500m in 2016. Sectoral shares are proportional to the sectoral share of the profit element of value added, which is taken from the Social Accounting Matrix (SAM), which his only available for Vietnam[25]. The basic layout of a SAM is described in Figure 24. Goods and services flow from rows to columns and payments flow from columns to rows. SAMs do not provide a direct estimate of investment by sector. They produce a sectoral breakdown of contributions to the capital account (in the value added box), but this is not the same as the investment by the sectors. The resources devoted to capital value added are delivered to institutions which then decide whether to consume or save and the savings are then allocated to investment by the institutions, which is delivered by the activities/sectors. Thus, in the SAM structure, reinvestment occurs when the institutions receiving factor incomes retain this for investment in their activities.

[25] *UNDP have recently supported the estimation of a SAM for Cambodia, but it is not yet published.*

FIGURE 24 Social Accounting Matrix Structure

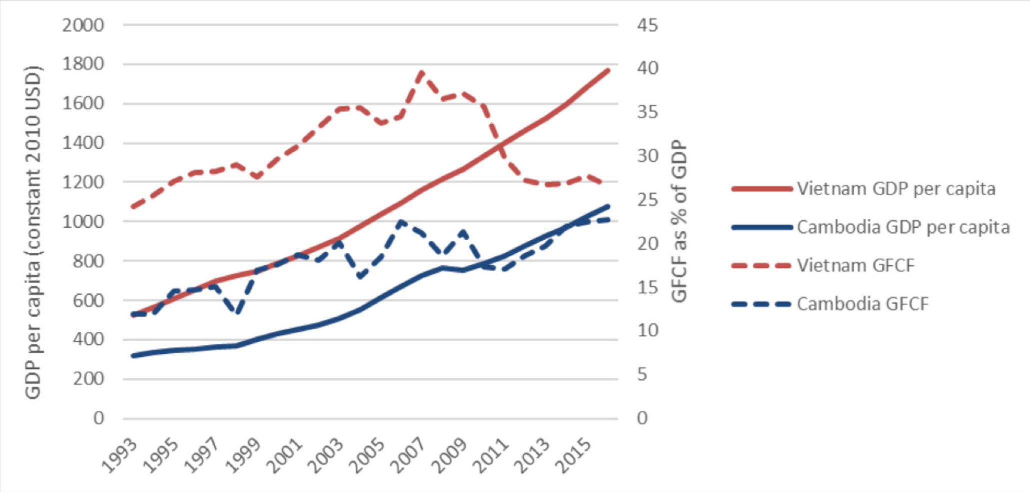
	Activities / Sectors	Factors	Institutions		Foreign	Capital
			Private	Govt		
Activities / sectors	Intermediate Inputs		Household consumption	Public services	Exports	Investment, stocks
Factors	Value added				Foreign Factor Earn.	
Private Institutions		Income / Revenue		Subsides transfers	Remittances	
Government	Producer taxes		Personal & Company tax		Transfers in	
Foreign	Imports		Repatriated earnings	Transfers out		
Capital			Savings	Public savings	Foreign savings	

However, the contribution of the sectors to the capital account is likely to influence the sectoral shares of investment for several reasons: firstly, the resources are often retained within households and enterprises and never exit to banks and other financial institutions; and, secondly, the capital income of each sector is a good indicator of the profitability of the sector and investment by banks is likely to be focused in the sectors that are most profitable. The approach used in calibrating the SAM model assumes that the share of sectoral value added devoted to the capital account is a proxy for sectoral investment. However, the total contributions of each sector to the capital account need to be adjusted to account for the fact that total capital account income is usually higher than total investment in the economy, because some capital account income is diverted into consumption and taxes, some of which are used to finance government consumption, rather than government investment.

Comparison with Investment History in Vietnam

To check the validity of this estimate, a comparison is made with the history of GFCF in Vietnam. The results are presented in the graph below. Cambodia is following a GDP growth path that is roughly 10 years behind that of Vietnam and had reached Cambodia's current GDP per capita in 2006. At that point, Vietnam's GFCF had grown fairly steadily for 10 years from about 28% of GDP to 35%. Cambodia's estimates for GFCF in the national accounts suggest that it was only 23% in 2006 and has seen little increase over the last 10 years. Given the concerns at NIS about the possible underestimation of GFCF in the Cambodia national accounts, and the similarity of the Cambodian and Vietnamese growth paths, ten years apart, it seems likely that Cambodia's GFCF will at least have matched the increase in GFCF that Vietnam experienced over the same stage of development, which would suggest a growth from 23% of GDP to 30% of GDP. This analysis therefore gives confidence that the estimate of GFCF used (ie 27.8%) is not too high and may, in fact, be too low.

FIGURE 25 Trends in Cambodian and Vietnamese Investment (GFCF) and GDP per capita

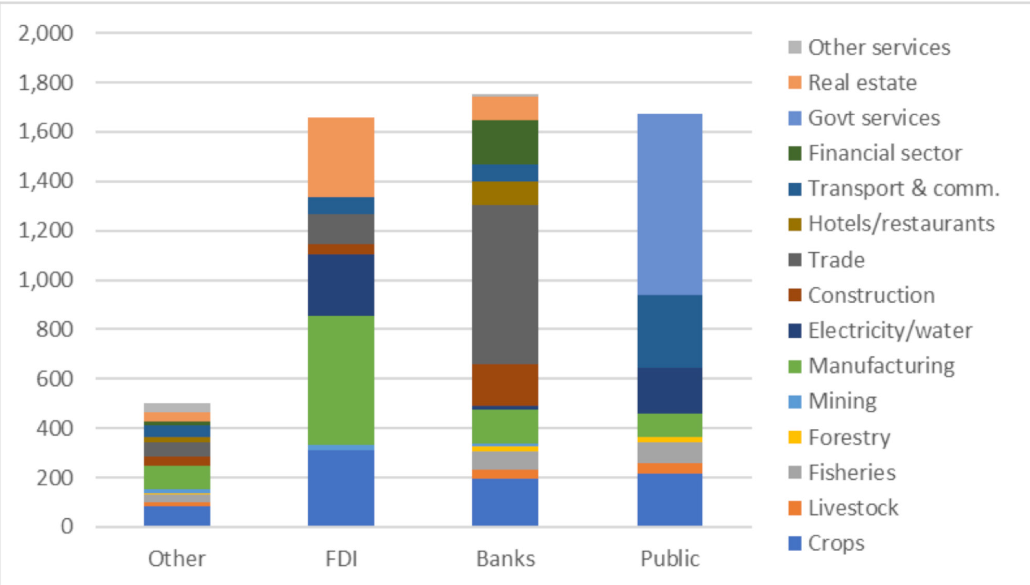


Source: national accounts statistics

Sector Shares of Investment

The figure below summarises the sector shares of the different sources of investment, showing how each sector relies on different sources of investment.

FIGURE 26 Sector Share of Investment by Source (USDm 2016)



Source: National Bank of Cambodia for Banks and FDI, PIP for public, other is the residual

ANNEX 3

Adaptation Effectiveness Case Studies

The analysis of Benefit Cost Ratio (BCR) and Adaptation Benefit Share (ABS) relies on Cost Benefit Analysis (CBA) in MAFF, MOWRAM, MPWT, MRD, MOH, MOE and CCFF over several years. Most of the cases refer to actual projects and locations. The benefit streams generally vary in accordance with the level of importance of those specific projects. Benefit streams also depend on evidence collected during those works.

Roads

Road BCR and ABS derives from the analysis of seven road CBA case studies in MRD and MPWT. The analysis of costs includes road investment cost with climate proofing option, periodic maintenance and annual maintenance. The benefit streams include travel time saving, VOC, reduced costs on maintenance and emergency repairs due to avoidance of flooding and Avoided disruption to road utilization due to more frequent rehabilitation.

- Road CBA analysis excludes several benefits such as access to school, access to market for farmers and poor, improved productivity or income, reduced health risks from dusts, Avoided flood damage to agriculture, and reduced GHG emission due to better road.
- BCR for road investment ranges from 2.4 to 5.3 and ABS ranges from 7% to 20%.

Irrigation

Irrigation BCR and ABS derives from the analysis of three irrigation CBA case studies in MOWRAM. The analysis of costs includes the construction (earthwork, general structure and others) with climate proofing option, annual O&M and major repairs. The benefit streams include improved wet season yield, improved and expanded dry season crop production, improved water supply for fisheries and domestic uses, avoidance of damages due to climate change, and reduced cost of maintenance and emergency repair due to climate change.

- Irrigation CBA analysis excludes several benefits such as road access from dam dike (school, hospital, and market), social cooperation in response to climate change, and the use of dike as alternative settlement of heavy floods happening surrounding villages.
- BCR for irrigation investment ranges from 3.0 to 3.3 and ABS ranges from 15% to 18%.

Flood Proofing Health Centres

Health centre BCR and ABS derive from the analysis of two health centre CBA case studies in MOH. The analysis of costs is the construction with climate proofing option. The benefit streams include cost saving on damages and loss of health centre infrastructure and equipment, time and transport cost saving for travel to alternative health centre during flooding, and avoidance of additional damages and losses due to more frequent floods due to climate change.

- Health centre CBA analysis excludes several benefits such as health damage saving due to delay in seeking treatment and prevention of further spread communicable diseases.
- BCR ranges from 2.9 to 3.4 and ABS is 28%.

CC Sensitive Diseases, Heath and Sanitation

BCR and ABS of sensitive diseases derive from the analysis of diarrhoea and dengue fever preventive measures case studies in MOH, and Malaria and Sanitation case studies in CCFF work. The analysis of costs includes the construction latrine with climate proofing option, annual O&M, marketing and servicing campaign. The benefit streams include health care cost avert, productivity loss saving, DALY saving, water access and treatment cost saving, and access time saving for open defecation, and avoidance of further costs due to climate change.

- CBA analysis excludes several benefits such as convenience values, safety value, and diseases contamination due to more frequent floods due to climate change.
- BCR ranges from 1.9 to 3.7 and ABS ranges from 4% to 15%.

Water Supply

Water supply BCR and ABS derive from the analysis of community water supply CBA case study in MRD and pipe water supply CBA case study in CCFF work. The analysis of costs for community water supply include the construction, annual O&M and periodic rehabilitation. The analysis of costs for pipe water supply include the construction of utility, pipe construction and O&M. The benefit streams include reduced cost and time for water collection and avoidance of water shortage during prolonged dry season.

- Water supply CBA analysis excludes several benefits such as water usage for small commercial farms and avoidance of higher cost of water collection during extreme drought.
- BCR for water supply investment from 2.9 to 4.1 and ABS ranges from 9% to 12%.

Renewable Energy and Energy Efficiency

The analysis BCR and ABS derives from two CBA case studies on micro-hydropower and LED installation in CCFF work. The analysis of costs includes the investment, installation and O&M. The benefit stream is mainly the electricity cost saving.

- The CBA analysis excludes benefits from availability of electricity for small commercial farms, improved operation of micro business and other social benefits (e.g. better education).
- BCR is between 4.2 and 4.5 and ABS is minimal.

Solid Waste Management

The analysis BCR and ABS derives from solid waste management CBA case study in MOE in Kampong Speu. The analysis of costs includes the annual operation cost of operator and M&E cost by MoE's officials. The benefit streams include health cost and DALY saved, local employment generation, revenue from recycle wastes and increased tourist visits, and damages saved from waste blockages to drainages due to increased floods and climate change.

- The CBA analysis excludes several benefits such as future revenues from transformation of waste into electricity, organic fertilizer from wastes, reduction of polluted airs and reduction of ground water contamination.
- BCR is 3.8 and ABS is 4%.

Coastal Adaptation

The analysis BCR and ABS derives from costal conservation in Prey Nob in MOE. The analysis of costs includes the investment in mangrove plantation and climate change awareness campaign. The benefit streams include increased fishery production, reduced rice and crop yield loss due to drought and rainfall variability, and reduced housing damaged.

- The CBA analysis excludes several benefits such as revenue from increased tourist to protected mangrove and coral reefs, job creation from fishery thus reduced migration, storm protection by mangrove and prevention of fast erosion of coastline due to climate change.
- BCR is 2.9 and ABS is 27%.

Wetland Management

The analysis BCR and ABS derives from wetland management in Prek Toal in MOE. The analysis of costs includes the annual preservation and protection of Prek Toal and replantation of flooded forests. The benefit streams include community fishing, water supply, non-forest timber product collection, flood and storm control and ecotourism.

- The CBA analysis excludes several benefits such as employment creation from ecotourism and fishery, biodiversity, and avoidance of water quality due to climate change.
- BCR is 3.5 and ABS is 31%.

Crop Research and Extension

The analysis of BCR and ABS derive from the crop research and extension delivering more resilient agriculture based on a CBA case study in MAFF. The analysis of costs includes the investment research on varieties and its extension. The benefit streams include average improved crop margins and risk aversion benefits.

- CBA analysis excludes several benefits such as improved food security and local employment generation and reduced migration.
- BCR is 2.5 and ABS ranges from 55%.

Rubber clone extension resilient to CC

The analysis of BCR and ABS derive from the rubber clone extension CBA case study in MAFF. The analysis of costs includes the extension investment by the government and rubber plantation investment by households. The benefit streams include average improved rubber yield with climate change context and sales rubber woods.

- CBA analysis excludes several benefits such as avoidance of risk of disease epidemics caused by climate change, by using new clone and local employment generation and reduced migration.
- BCR is 2.4 and ABS ranges from 8%.

Forestry Protection

Forestry BCR and ABS derive from the analysis of two forestry protection CBA case studies in MOE and MAFF. The analysis of costs is the community set-up cost, annual management and opportunity cost on commercial deforestation. The benefit streams include increased agricultural outputs, increase livestock production, water supply and non-timber forest products, and avoidance of loss of these benefits due to climate change.

- Forestry CBA analysis excludes several benefits such as employment for local community and reduced migration, biodiversity, traditional medicines, and health benefits due to purified air.
- BCR ranges from 1.8 to 2.0 and ABS ranges from minimal to 20%.

Biodigester from Cattle Dung (Livestock)

The analysis of BCR and ABS derive from the biodigester CBA case study in MAFF. The analysis of costs includes the construction and maintenance of biodigester by households. The benefit streams include electricity production, bio-fertilizer saving and increased yield of crops and vegetables, and reduced health risk.

- CBA analysis excludes several benefits such as time saved for fire wood collection, bright lights for children readings, and reduction of deforestation.
- BCR is 2.6 and ABS is minimal.

Fish Refuge Pond Community (Fishery)

The analysis of BCR and ABS derive from the fishery CBA case study in MAFF. The analysis of costs includes the pond and canal construction, O&M and purchases of small fishes. The benefit streams include reduced food costs, sales of fertilizers from sludge, and irrigation of rice field.

- CBA analysis excludes several benefits such as food security, and increased human nutrition especially for vulnerable groups.
- BCR is 6.4 and ABS ranges from 6%.

Supported by

CAMBODIA CLIMATE CHANGE ALLIANCE

Implemented by: Ministry of Environment

Supported by: European Union, UNDP (Empowered lives. Resilient nations.), SWEDEN

GOVERNANCE OF CLIMATE CHANGE FINANCE TO ENHANCE GENDER EQUALITY IN ASIA PACIFIC

www.CFADE.org